

**FAIRCHILD**  
REPUBLIC DIVISION

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## **PREFACE**

**This document is DRL Line Item No. 4, Final Report,  
of Contract NAS9-12205, Spacecraft Sanitation Agent.**

**The information contained herein is a compilation of the material  
contained in the Task I, Task II and Task III reports.**

**SECTION 1.0**  
**INTRODUCTION**

In August 1971 the National Aeronautics and Space Administration contracted with the Fairchild Republic Division (FRD) of Fairchild Industries for the development of a SPACECRAFT SANITATION AGENT.

Although there had been considerable recognition of the bacterial problems associated with long duration space flights, there had been little effort to develop a general all-purpose sanitation agent that would be effective and yet compatible with the spacecraft environment.

NASA had proceeded with the development of numerous items of flight hardware with the assumption that a sanitizing agent would be available for cleansing and decontamination; it was the effort under this contract to designate the agent.

The selection of sanitizing agents for space is no simple task. Even for earth application, it is generally agreed that there is no perfect antiseptic or cleansing agent and this is illustrated by the thousands of compounds that have been manufactured, used, and discarded. In space, the problems become magnified due to conditions imposed by the space vehicle environment, materials, and systems. There are two fundamental paradoxes concerning antimicrobial agents and their use which are the cause of the problem, these are:

- 1) In order to kill bacteria, a bactericide must, obviously, be toxic to bacteria. But, since the biology of bacterial protoplasm is not substantially different from the biology of human protoplasm in many respects, bacterial toxicity must be accompanied, to some degree, by human toxicity.
- 2) In order to penetrate the living bacterial cell and destroy protoplasm, a bactericide must be chemically reactive. The same property causes it to react with substances other than bacteria, i. e., few bacterial agents are truly selective and, therefore, cause undesired incompatibilities.

Thus, although there was no perfect agent, there were preferred agents for specific application, and it was the intent of this study to perform the trade-offs that will select the best agent or agents for space use. The problem was very much more

than a question of bacteriology. It involved the full spectrum of life support in space - the human, the hardware, and all of the interfaces that existed between them.

Under this contract, Fairchild has developed sanitation agents and techniques for space station use. This was done in three tasks and reported as follows:

- Task I: A definition of sanitation requirements, with crew level requirements and system level requirements. Engineering and Technical Data Report, Definition of Use Requirements for Sanitation Agents/Techniques (MS142Y0007) has been prepared and submitted.
- Task II: A selection of sanitation agents and techniques for personal hygiene and crew systems, metabolic and expendable waste storage, techniques and schemes, and maintenance servicing of contamination sensitive subsystems. Engineering and Technical Data Report, Sanitation Agent/Technique Selection (MS142Y0008) has been prepared and submitted.
- Task III: Evaluation testing for antimicrobial effectiveness, surface active properties, materials compatibility, space system compatibility, stability, and toxicity over the range of environmental conditions specified in the contract. Engineering and Technical Data Report, Evaluation Testing, MS142Y0009 has been prepared and submitted.

This volume, DRL #4, Engineering and Technical Data Report, Final Report, summarizes the Task I, Task II and Task III documents.



## SECTION 2.0 TECHNICAL APPROACH

This study has defined spacecraft sanitation requirements and selected sanitation agents with appropriate techniques for use in space systems. The technical approach flow diagram shown in Figure 2-1 shows the steps taken in the development of the sanitation agents. A discussion of each of these steps is presented in the following sections.

### 2.1 DEFINE USE REQUIREMENTS FOR SANITATION AGENTS/TECHNIQUES AND PROCEDURES

In this study, the level of acceptable bacterial contamination for the maintenance of functions was considered using as a baseline current knowledge of closed space cabin and clean terrestrial environments such as hospitals and laboratories.

In establishing the definition of use requirements, data from many different NASA/USAF/Fairchild Republic studies was used. Table 2-1 summarizes the source material used for the requirements definition.

### 2.2 DEFINE SPACE SYSTEM INTERFACES

Antibacterial agents must be toxic and chemically reactive. This immediately restricted the use of an agent to those situations where the toxicity to human tissue would not be detrimental, and where the reactivity with materials is permissible and within definable limits.

To toxicity and reactivity must be added the factor of time. There is generally an inverse relationship between strength and time of exposure, i. e., a very strong agent will kill rapidly. Because a strong agent may be undesirable because of its toxicity and reactivity, a common approach is to decrease the strength and increase the exposure time.

These trade-offs were considered from the viewpoint of their use in space systems. Constraints which also impacted the sanitation agent included:

- 1) Use/application in space systems, e.g., applied with a wipe or swab, flowed through tubes, valves, etc., or sprayed on surfaces. This also includes zero-gravity aspects.

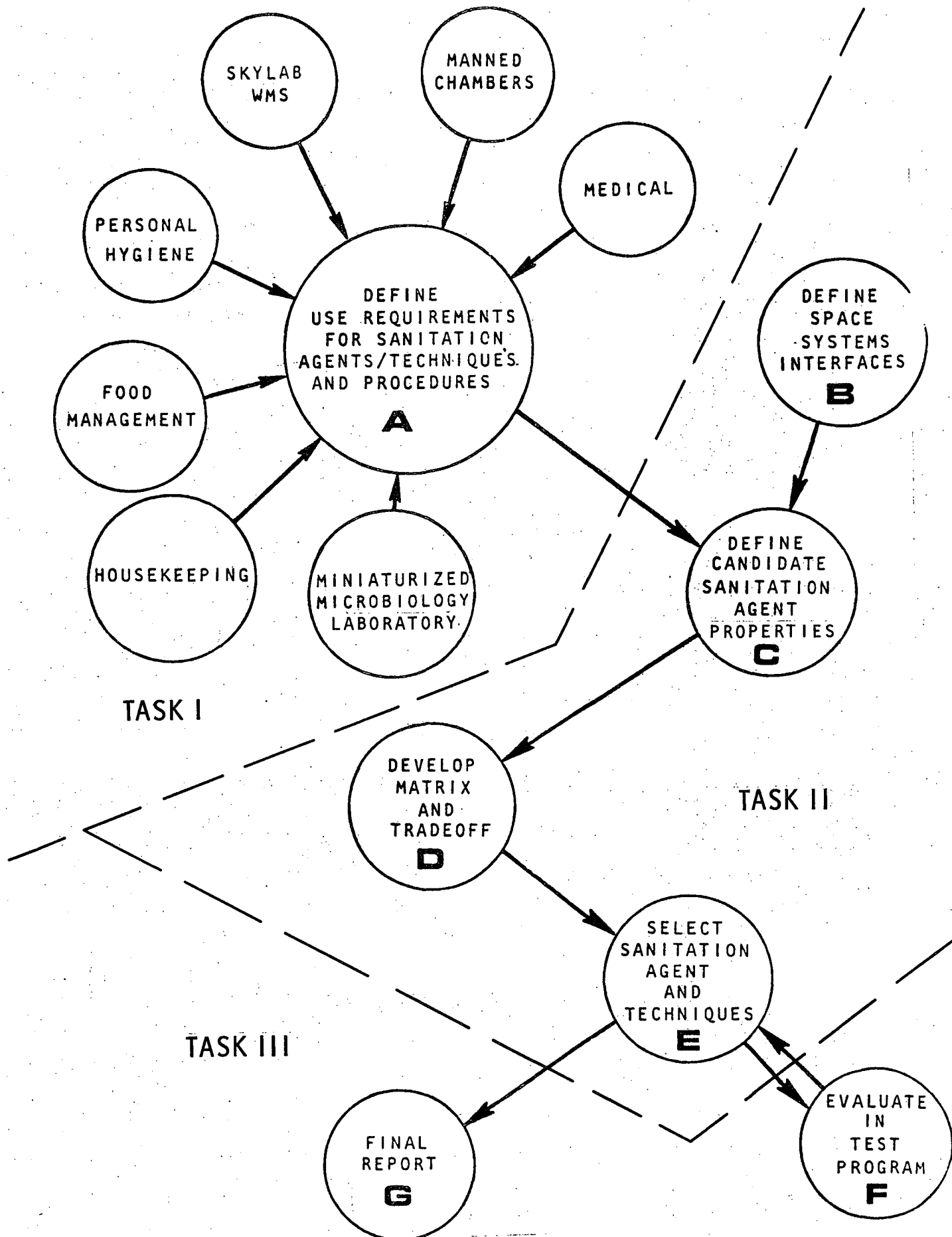


Figure 2-1. Technical Approach Flow Diagram

TABLE 2-1. SUMMARY OF SOURCE MATERIALS

Study	Contract	Scope
Housekeeping Concepts for Manned Space	NAS9-10662	Defined waste materials, sources, quantities and characteristics
Preliminary Design and Development of House-keeping Systems for Manned Spacecraft	NAS9-11995	Defined contamination tolerance levels, steward duties and housekeeping equipment (collection bags, vacuum cleaner, compactor)
Manned Chamber Study	AF-FT33615-57-C-1833	Defined microbiological control requirements
Skylab Waste Management Subsystem Study	NASA/MSFC NAS9-6555-1 (MDAC)	Defined sanitation of human wastes and associated systems
Personal Hygiene Study	NAS9-11509	Defined human sanitation requirements
Food Management Study	NAS9-11139	Defined feeding systems and their sanitation requirements Included were designs for a zero-to-partial-g sink and dish/utensil washer
Laundry Study	In-house	Fabrication and zero-g test of high agitation efficiency, low water usage laundry
Shower Study	In-house	Fabrication and zero-g flight test of model
Astrovac Study	In-house	Fabrication and test of mechanical body wipe device.

- 2) Compatibility with spacecraft materials, e.g., reactivity with metals and/or plastics.
- 3) Compatibility with spacecraft systems, e.g., interference with electronic or mechanical systems.
- 4) Toxicity to humans, both superficially and internally.

### 2.3 DEFINE CANDIDATE ANTISEPTIC PROPERTIES

Based upon the established requirements and the constraints applied by the space system interfaces, the properties of a desired sanitation agent were stated. Here, also were noted incompatibilities, use form, microbial toxicity, human toxicity, stability, and all of the other properties that apply to either general or specific use.

### 2.4 DEVELOP MATRIX AND TRADE-OFF

With the required properties of a space sanitation agent clearly defined, the next task was to evaluate all of the known appropriate chemicals for their ability to satisfy their requirements. This was done in a trade-off study. Both pure chemicals and proprietary formulations were evaluated.

### 2.5 SELECT SANITATION AGENT AND TECHNIQUE

The trade-off led to the selection of desirable sanitation agents. It was determined at this time that a single sanitation agent was unsatisfactory, and a formulation incorporating several agents must be made.

Also determined at this time were the techniques for application, both in general use and in specific application.

### 2.6 VERIFY IN TEST PROGRAM

Candidate sanitation agents were analyzed for environmental criteria and performance criteria. These tests included materials compatibility, stability, 100% oxygen storage and usage and microbial effectiveness. Standard tests and procedures were used in this evaluation.

### 2.7 FINAL REPORT

From this total effort, NASA is receiving this final report which identifies the spacecraft sanitation requirements/techniques and the spacecraft sanitation agents capable of satisfying each requirement. In addition, additional areas of investigation are recommended.

SECTION 3.0  
DEFINITION OF USE REQUIREMENTS (TASK I)

This phase of the contractual effort was a definition of the requirements for spacecraft sanitation, including the agent, the techniques, and procedures. It was an attempt to take the best current knowledge on manned space habitability and establish quantitative and qualitative requirements which could be met by appropriate pharmaceutical and life support/habitability engineering.

The task was by no means simple because man cannot exist in a completely sterile contamination-free environment. He is both a reservoir of microbes and a generator of metabolic waste. There was some question if even "near-sterility" was desirable because of the role of microorganisms in maintaining normal human indigenous flora. Man exists with acceptable levels and types of microorganisms on earth and should probably continue to do so in space.

Nor was there any direct relationship between lack of sanitation and the impairment of health. The presence of filth did not necessarily imply the presence of pathogens, nor individual susceptibility to the pathogens even if present. History and personal experience confirm survival and continuing human performance through the unsanitary conditions of the middle ages, battles and prisons, and recreational camping.

It becomes apparent that the human in our society engaged in sanitary practices principally for aesthetic reasons. America spends seven billion dollars annually on personal grooming products (toilet soaps, cosmetics, shaving creams, etc.) whereas, only two hundred and seventy-three million dollars are spent on general purpose sanitation agents. The only rationale for the massive expenditure on personal grooming is the intense desire to look, smell and feel clean.

In spite of the enormous interest in personal products, there was nothing that established firm cause-effect relationships between level of superficial bacteria and soil and the personal sensation of cleanliness. The criteria for evaluation and acceptance were subjective, making translation into engineering requirements difficult.

Two other reasons for sanitizing were medical and functional. Sanitation for medical reasons, i.e., the prevention of disease, is a common procedure in situations where

pathogenic microbes can proliferate (toilets, food preparation areas, etc.), and of paramount importance where pathogens abound (hospitals, sick rooms, etc.). Again, unfortunately, the levels of acceptable microbial contamination are working levels that are obtainable in use situations. They are not absolute levels that guarantee the absence of any and all pathogens. Table 3-1 shows the populations which are experienced in hospitals, and serves as a guide to the desired best level of microbial contamination in this study.

The medical basis for the removal of soil other than bacteria is very vague. Toxic materials and drying substances on the skin must be removed promptly and completely to avoid dermatitis. But oil on the skin is usually beneficial, and excessive cleansing can be more harmful than no cleansing. Again, there are no quantitative standards for superficial soil for health and well being.

TABLE 3-1. TOLERABLE CFU\* VERSUS HOSPITAL AREAS

No.	Area Description	Tolerance Range - CFU*		
		Good Conditions	Fair Conditions	Poor Conditions
1	Critical Areas (e.g., operating rooms, isolation wards):			
	• Floors	< 5	5-15	> 16
	• Table/counter tops	< 5	5-10	> 11
2	Patient Rooms			
	• Floors	< 25	25-50	> 51
	• Table/counter tops	< 10	10-15	> 15
3	Bathrooms			
	• Floors	< 25	25-50	> 51
	• Sinks and tubs	< 15	15-25	> 26
	• Toilet seat	< 10	10-15	> 16
4	All Other Areas			
	• Floors	< 25	25-50	> 51
	• Other horizontal surfaces	< 5	5-8	> 9
5	All Swab Samples	< 10	10-30/sq. in.	> 31
6	Room Air Samples	< 10	10-30/cu. ft.	> 31

\* All counts are in colony forming units (CFU) and are an average of individual plate counts.

Functional sanitation relates to the performance of a system in a contaminated environment. The contamination sensitive systems on a space vehicle are typically the life support systems, but they include any other systems on which organisms might proliferate or soil accumulate. The requirements for sanitation must be specified for each system and its components, and this is unfortunately in a constant state of flux. NASA has recognized the problem in establishing the Intercenter Working Group for Skylab Microbial Contamination Control. NASA specifies that flight items be clean at the time of delivery, but they acquire soil as a result of use. The extent to which this soil is undesirable is a function of the susceptibility of the component, e.g., soil on a control knob has little impact and requires little or no sanitation, soil on a meter face is more critical because it impairs reading and requires periodic simple sanitation, soil in an air filter is still more critical because it impairs function and efficiency and requires more thorough sanitation, and soil on an electrical contact destroys function and, therefore, must be completely sanitized or never permitted to reach a critical area.

Thus, in the performance of this study, Fairchild has had to make numerous value judgments concerning the level of contamination to be expected and the need for sanitizing - both attenuation of microbes and the removal of soil. These judgments were based upon many years experience with manned space systems. Fairchild believes them to be valid within the current state-of-the-art.

### 3.1 METHOD OF STUDY

A flow diagram depicting the method of study is shown in Figure 2-1.

#### 3.1.1 Source Material

The sources used principally in the identification of space sanitation requirements were identified in Table 2.1.

#### 3.1.2 Functional Analysis

Each of the sources cited in Table 2.1 were analyzed for the requirement for a sanitizing agent. A functional analysis of these requirements was made. A format was prepared (Figure 3-1) on which each item that required sanitizing was listed.

Each listing contained the following information:

- Contaminated Source -- This column refers to the sources or system of the item that requires sanitizing, e.g., the waste management system, food system, or the human body.

[illegible]

**Figure 3-1. Functional Analysis Work Sheet**



- Reference (Ref.) -- Refers to the study or document which supplied the information.
- Material Characteristics -- Under this heading are listed two separate characteristics.
  1. Soiled item - This is the specific soiled item, e.g., a valve, a spoon, or the hand.
  2. Category - Categories A or B or C refers to the materials to be sanitized and are defined as follows:
    - A. "Agents for crew use in personal hygiene, clothes washing, dish/utensil washing, etc."
    - B. "Techniques and agents for management of metabolic waste (feces, urine, and vomitus) storage prior to processing, food wastes, ECS expendables e.g., charcoal and bacterial filters) and miscellaneous trash."
    - C. "Methods and material for maintenance servicing (i.e., ECS expendable removal and replacement or plumbing repair) of contamination sensitive subsystems . . . ."
- Threat -- The threat is the reason for sanitizing. It implies some measure of the impedance for sanitizing and influences the evaluation of the characteristics of sanitizing agents. Listed in decreasing order of importance, they are M, F, and A.
  - M. A medical threat, presenting a hazard to health and life. This would be limited to the presences of pathogenic microorganisms, toxins, or substances which would have a deleterious effect on psychomotor performance.
  - F. A functional threat, presenting an interference with system function. This would include materials which would clog, contaminate, or otherwise inhibit or fail the function of the item.
  - A. An aesthetic threat, presenting an unpleasant psychological sensation. This is highly subjective, and includes such things as body odor, dirty eating surfaces, or other lack of housekeeping or personal hygiene which would be significantly less than the standard of living of the astronauts.
- Soil Characteristics and Load -- Under this heading are listed the five characteristics of the soil which must interact with the sanitizing agent.
  1. Metabolic - This category of soil comes from the human or animal organism. It includes all body fluids, hair, skin, and sebaceous secretions.
  2. Nutrient - This type soil is organic, non-metabolic, which is capable of supporting microbial growth. Included in this category are food, grease, oils, soaps, charcoal, etc.

3. Microbial - This category is the microbial load or relative number of microorganisms. It indicates the need for antimicrobial agents and their strength.
4. Grease - This category is the quantity or load of grease, which sets the requirement for surface active properties.
5. Grit - This category is an assessment of particular matter contained in a waste.

A numerical assessment of 0 to 5 was made for the quantity or load of each of the characteristics.

0	-	None
1	-	Light
2	-	Moderately light
3	-	Moderate
4	-	Moderately heavy
5	-	Heavy

- Indicated Sanitation Action -- The obvious or simplest techniques for sanitizing were listed. These techniques could be modified by future engineering considerations.
- Disposal of Final Product -- This related only to the used sanitation agent, the material treated with the agent if disposable, the means of supplying the agent or the rinse water.

### 3.2 CREW LEVEL REQUIREMENTS

The crew level requirements were established on the basis of Fairchild Republic's NASA study "A Baseline Protocol for Personal Hygiene." An analysis of the biological requirements was made, relating to the need for microbiocidal or microbiostatic properties. The basis for establishing the biological requirements was contemporary medical microbiological practice from numerous sources.

The requirements for personal hygiene sanitation must be maintained by a sanitizing agent used on the human body. These requirements were:

#### a. Whole Body Wash

A shower is the most desirable and satisfying method of whole body personal hygiene. A sanitation agent is required to remove superficial sebum. There is no requirement for cutting heavy grease. The skin requires that all implements and materials, e.g., water, be clean prior

to application. Although showers and sinks may exist the agent should also be capable of being used without a water rinse. A surfactant is required to improve surface penetration.

b. Hand and Face Wash

A standard hand sink is the most desirable method of satisfying the requirements of a hand and face wash. The agent must be able to remove large amounts of grease. A surfactant is required to improve surface penetration. The agent should be capable of being used without a water rinse.

c. Hair Hygiene

A sanitation agent would be required to prevent cross contamination among users since it is not envisioned that more than one hair clipping instrument will be provided. Therefore, the agent must be potent and not leave a residue.

d. Shaving Capability

A sanitation agent would be required to prevent cross contamination among users if any implements other than the shaving cream and razor are employed.

Besides these cleaning requirements, the sanitation agent must also satisfy the following biological requirements:

- The sanitation agent must inhibit microbial growth
- The sanitation agent must be nontoxic and nonallergenic

The sanitation agent is required to inhibit the microbial growth of all those organisms that are considered indigenous to man. These include cocci, gram positive bacilli, gram-negative bacilli (aerobic and anaerobic) spirilla, spirochetes, fungi, PPLO and viruses. This necessitates that the sanitation agent be able to inhibit the growth of a broad spectrum of microorganisms.

A surfactant is regarded as an essential ingredient in any sanitation agent used for personal hygiene. The surfactant enables the crewmember to attain a very high degree of cleanliness. However, the incorporation of any surfactant into an existing sanitation agent requires that the resulting compound be nontoxic. It would appear, therefore, that the effects on the skin by various surfactants imposes still another hurdle in the selection process. The greater the complexity of the surfactant composition, the greater the possibility of an allergic dermatitis.

### 3.3 SYSTEM LEVEL REQUIREMENTS

The analysis of system level requirements was divided into sections; system level maintenance and contamination sensitive subsystems. These requirements were established based upon data obtained from NASA chamber studies and the Skylab waste management system operation and maintenance requirements. An analysis of biological requirements and material compatibility was also conducted.

The NASA Housekeeping Study contract with Fairchild Republic Division, NAS9-10662, defined the wastes that will be generated on extended life orbital stations with crews of from 6 to 100 men.

Based upon the above data it would appear the only trash which will require sanitation, is that which is already contaminated with bacteria or that which can support microbial growth.

#### 3.3.1 System Maintenance

It is expected that man will be the sole source of significant contamination since he is a reservoir of multiplying microorganisms. If this is a true assumption, any material that is not handled by any member of the crew could be safely discarded. It is assumed that any necessary systems repairs will be carried out aseptically using clean room techniques.

Surfaces will normally be contaminated with minor amounts of grease, grit and microbial contamination. Therefore, it would appear that normal cleansing procedures would be applicable. Dry wipes and/or wet wipes with a sanitation agent should cover the major surface cleaning requirements. These, in turn, must be deposited for further handling in a collection receptacle. In the event of the deposit of major quantities of metabolic wastes, such as the inadvertent depositing of vomitus, the presence or absence of biomedical monitoring requirements must be taken into account. In the absence of these requirements, treating the waste at the site by adding an inert agent before further handling may be desirable. The presence of the requirement may preclude adding anything until the wastes are blended, a sample extracted and their mass determined.

The maintenance of sanitary conditions in the waste management subsystem, galley and dining facilities, and laboratory areas is extremely important, since these areas usually contain either high grease, and/or grit, and/or microbial loading.

### 3.3.1.1 Waste Management Subsystem

The waste management subsystem must be flushed after each use. The sanitation agent, therefore, must be effective in the presence of large quantities of organic material. The external surfaces, i.e., toilet seat, hand restraints would be scrubbed with a "wipe" and bactericide on a daily basis. Any spillage should be treated according to the procedures outlined in Table 3-2. These requirements are applicable to Skylab. However, no bactericidal flush is required in the use of the Skylab waste management subsystem.

### 3.3.1.2 Galley and Dining Facilities

The procedures adopted during the 90-day test of a regenerative life support system are applicable to all missions modes and should be used extensively to prevent large accumulations of food wastes. These food wastes besides already containing micro-organisms could also serve as a nutrient source to enhance the growth of any micro-organisms brought into contact with this material. The procedures used included instructing the crew in licking their food trays clean prior to spraying them with a disinfectant. These food trays were then stowed in environmentally sealed aluminum boxes. Utensils, if reusable, are placed in a dish washer. The wash water is reclaimed via the potable water system. Disposable utensils are wiped with a bactericide and placed in a collection receptacle. Left over food wastes exceeding several grams should be scraped from the food trays and placed in a waste container. The contents of the container are then sprayed with a bactericide.

As a routine maintenance the dining tables should be cleaned with a bactericide after each use. Any spillage of debris, both liquid and solid, would be treated as outlined in Table 3-2.

### 3.3.1.3 Laboratories

The laboratories must be cleaned after each use. Laboratory utensils must be maintained in a completely sterile condition. If the utensils are reusable they must either be placed in a sterilizer or wiped with a bactericide. Test tubes and petri dishes would be sterilized by spraying the bactericide inside. All disposable items would be inactivated by wiping with a bactericide and then collected in a trash receptacle containing the bactericide. Any spillage of debris would be treated as outlined in Table 3-2.

TABLE 3-2. CLEANING PROCEDURES

Urgency Category	Vacuum	Dry Wipe	Wet Wipe (Bactericide)	(Note 3)		
				Autoclave Materials	Compactor/ Shredder	Store
1. Normal Maintenance	R	A	A	A	A	A
2. Condition Requiring Immediate Sanitation Action						
• Liquid Spillage	I	X	X	N/A	N/A	X
• Food Spillage	I	X	X	X	N/A	N/A
• Dust (powders) present	R	N/A	X	N/A	N/A	X
• Microbially contamin- ated material present	I	N/A	X	X	N/A	N/A
3. Debris Removal						
• Metallic Wastes	R	N/A	N/A	N/A	X	X
• Chemical Wastes	S/I	X	N/A	N/A	X	S
• Radioactive Wastes	S/I	X	N/A	N/A	S	S

Legend. X = Procedures indicated are valid candidates  
N/A = Procedures indicated are not applicable.

A = Apply as applicable.

Note 1. R = Maintain routine area cleaning schedule.

I = Requires immediate cleaning action.

S = Special handling and treatment required.

Note 2. Only if Autoclave facility is available.

### **3.3.2 Contamination Sensitive Subsystems**

The contamination sensitive subsystems that have been included in this analysis are the potable water subsystem, wash water recovery subsystem and the environmental control subsystem.

#### **3.3.2.1 Potable Water Subsystem**

The potable water subsystem, used in the operational ninety-day manned test of a regenerative life support system was operated on a principle of multifiltration. The potable water must be certified before use. A bactericide should be added to the holding tanks to prevent microbial contamination of the potable water. The attachments and fittings must be treated with a bactericide whenever the water produced by the potable water system fails to meet the prescribed standards. The sanitation agent must meet all the toxicity criteria necessary for it to be approved for internal consumption without substantially altering its bactericidal properties.

#### **3.3.2.2 Wash Water Recovery Subsystem**

The wash water recovery subsystem, used in the operational ninety-day manned test of a regenerative life support system was the system considered for this analysis. Waste water used for personal hygiene, laundry and spillage, etc., will be recovered via this system. The water will be analyzed both chemically and microbiologically for purity. A bactericidal agent used in this subsystem should be highly bactericidal, non-detergent and biodegradable. The particulate filters would be aseptically changed. The area of attachment would be wiped with the bactericide. The dirty filter would then be removed and placed in a trash receptacle containing the bactericide. Charcoal would also have to be changed aseptically. The contaminated charcoal would also be placed in a trash receptacle containing a bactericide. The sanitation agent must retain its effectiveness in the presence of organic material.

#### **3.3.2.3 Environmental Control Subsystem**

The environmental control subsystem used in the operational ninety-day manned test of a regenerative life support system consisted of the following:

- Thermal Control Unit -- This unit consisted of filters, supply and discharge acoustical traps, twin blowers, extended surface heat exchange, perforated supply diffusers and electronic controls.

- Toxin Control Unit -- This unit consisted of a regenerative heat exchanger, an electric heating element, a temperature controller and a catalytic reactor.
- Molecular Sieve Carbon Dioxide Concentrator Unit -- This unit consisted of a circulation blower, two molecular sieve beds in parallel, heat exchanger, zero-g water separator, timer, manifolds and sequence control valves.

A sanitation agent would be required if any maintenance or replacement of any equipment was necessary. The sanitation agent would be used to sterilize both the replacement and the defective equipment. Filters would have to be removed, sterilized, and replaced by new ones.

### **3.3.3 Materials Compatibility**

Due to the demand of high reliability in manned spacecraft, extremely stringent requirements have been placed upon the use of non-metallic as well as metallic materials. As a result of these demands a set of tests have been established and enforced by NASA/MSD in accord with D-NA-0002. To qualify for use in a manned space vehicle, a material must pass flammability, flame propagation, odor, and outgassing tests in pure oxygen. As a result, most of those materials which have been screened out, have been generally inert except in the area of corrosion. Susceptibility where each and every alloy can react differently to any one particular media. This is in fact the problem in evaluating space grade materials with candidate sanitation agents. There has been no specific testing found in the literature. Iodophors for example have good kill power but are also considered highly corrosive as all halogens are; quaternary ammonium chlorides are considered noncorrosive by the chemical manufacturers but they offer no written substantiating data, however, limited data on ammonium chloride suggests a serious corrosion problem. Hence, candidate sanitation agents must be tested for compatibility to any and all interfacing materials aboard the spacecraft and under those environmental conditions normal to the spacecraft.

### **3.3.4 Biological Requirements**

The sanitation agent selected to clean the spacecraft system must also meet several biological requirements. These biological requirements are:

- Inhibition of microbial growth
- Toxicity



#### 3.3.4.1 Inhibition of Microbial Growth

The selected sanitation must either completely inhibit microbial growth or effectively reduce the microbial population to an acceptable level. The action of the sanitation agent may be bacteriostatic or bactericidal. Contamination tolerance levels, based upon hospital standards, were established for all types of missions. The following factors were also considered:

- 1) The duration of the mission, e.g., 2 days, 7 days, 30 days, etc.
- 2) The type of mission, e.g., experimental or resupply
- 3) The number of crewmen and the activities assigned to them associated with fulfilling the mission requirements
- 4) The amount of time allotted for routine housekeeping and maintenance

Another important factor to consider before establishing contamination tolerance levels for each spacecraft functional area is the type of activity being conducted in the area. For example, a specific type of waste would be produced in the galley which would be treated differently than a waste product produced in the control room. This is evident from the functional analysis since the wastes produced in the galley contain a high level of nutrients and microbial flora, whereas the wastes produced in the control room do not.

The waste management subsystem will contain the largest amount of organisms. Members of the family Enterobacteriaceae make up a large part of the aerobic microbial flora of man. These include the intestinal commensals (the coliform bacilli and species of proteus), as well as the enteric pathogens of the salmonella and shigella genera. Intestinal streptococci (enterococci), species of bacteroides (probably the predominant germs in the normal stool), clostridia, and various yeast forms (including Candida albicans), as well as, on occasion, pathogenic staphylococci are also present. Vibrio comma the causative agent of cholera and occasionally Mycobacterium tuberculosis may also be isolated.

At least 60 species of virus have been recovered from the intestinal tract of man. These viruses comprise mainly three groups: the polio viruses, the Coxsackie viruses and the Echo viruses.

The galley can be a source of any of the above microorganisms. However, S. aureus and C. perfringens, the causative agents of food poisoning, are the most virulent organisms that must be inhibited.

The potable water subsystem seems prone to contamination with Pseudomonas aeruginosa. This organism is extremely resistant to attack by antimicrobial agents and a concentrated solution of disinfectant must be used.

The environmental subsystem filters are susceptible to contamination by all the microorganisms present in the entire craft. Extreme care must be taken to insure the sterility of this subsystem during maintenance operations since any contamination would be disseminated throughout the craft.

The laboratories will contain large sources of microorganisms. Extreme care must be taken to maintain the integrity of the envelope to prevent contamination of the entire spacecraft. Any sanitation agent used in this area must be effective against all types of organisms.

#### 3.3.4.2 Toxicity

An internal toxicity requirement must be added to the biological requirements already established. This is necessary because of the requirement to maintain the contamination level in the potable water subsystem. This requires that the concentration level of the sanitation agent used be compatible with crew consumption.

### 3.4 DEFINITION OF SPACE SANITATION AGENT

Based upon a functional analysis of the need for a space sanitation agent, its use techniques and crew and system requirements, the space sanitation agent was defined. This definition served as the basis for agent selection, Section 4.0 (Task II), and was based upon the following categories:

- Category of use
- Threat
- Soil characteristics and load
- Technique (indicated sanitation action)

- Disposal of final product
- Environmental requirements
- System requirements
- Crew requirements

#### 3.4.1 Category of Use

- The agent must be compatible with human skin, and to a lesser extent sensitive exposed outer tissue (eyes, oral mucosa, etc.). This measurement includes chemical toxicity, allergic response, and removal of normal sebum. It must be non-toxic if ingested in small quantities.
- The agent must retain effectiveness in the presence of high concentrations or organic matter, such as feces, vomitus, or body oils.
- The agent must be effective in removing soil and inhibiting microorganisms on metal and plastic surfaces. A residual biocidal effect is desirable. Sudsing is to be held at an absolute minimum.

#### 3.4.2 Threat

The agent must satisfy the removal of the following "threats" listed in decreasing order of importance:

- Medical
- Functional
- Aesthetic

#### 3.4.3 Soil Characteristics and Load

##### 3.4.3.1 Metabolic

The requirement for the sanitation agent in treating soil containing metabolic wastes is principally in personal hygiene and the waste management system and to a lesser extent in habitability areas, laboratories, and sick bays.

- The agent must be effective in sanitizing metabolic waste. This includes the removal of fecal stains, the solubilizing of the oil components of vomitus, deodorizing, and the attenuation of a broad spectrum of bacteria.
- When used as a personal hygiene cleanser, the agent must be effective in removing excess sebum and superficial flora.

#### 3.4.3.2 Nutrient

The principal nutrient soil application was the cleaning of the food management systems and dining areas, and to a lesser extent, the removal of residual metabolic waste from the waste management or personal hygiene areas.

- The agent must be effective in cutting food soil, including grease, coagulated protein films, and animal and vegetable fats and oils.

#### 3.4.3.3 Microbial

The microbial load was highly variable, from negligible to extremely heavy. In the interest of safety, the requirement for effective microbial control was established for all use situations, regardless of the actual number of microbes present.

- The agent must be effective in exerting a biostatic effect against the organisms presenting a broad spectrum of gram positive and gram negative bacteria, fungi, and protozoa, as demonstrated, for example, in the Kolmer test against S. aureus (FDA strain No. 209), Salmonella typhosa (Hopkins strain), C. albicans, M. tuberculosis, Bacillus sp., and Trychophyton mentagrophytes.
- The agent must be effective in maintaining bacterial counts at the acceptable level in a manned cabin environment, when used in accordance with a suitable technique.

#### 3.4.3.4 Grease

The principal requirement for cutting grease was in food management. In no case was a heavy grease cutting action required, except for some lubricants which would be dry wiped.

- The agent must have moderate grease cutting effectiveness against low concentrations of animal and vegetable fats and oils.

#### 3.4.3.5 Grit

The grit removal requirement was minimal, consisting mainly of food crumbs, dust and metal flakes.

- The agent should attract and entrain, rather than repel, small particles of grit.

**3.4.4      Technique (Indicated Sanitation Action)**

The agent must be capable of being applied by each of the following:

- Preloaded dry wipes
- Wet wipes (sponges, cloths, etc.)
- Direct application
- Aerosols in confined spaces

**3.4.5      Disposal of Final Product**

The agent must be totally removed by rinsing with water or dry wiping, except for a quantity necessary to exert a permissible residual biostatic effect.

**3.4.6      Environmental Requirements**

**3.4.6.1      Materials**

The agent must be compatible with all potential spacecraft materials, both organics and metallics. If the agent is incompatible with a limited number of critical materials, these incompatibilities must be defined and overall value depicted.

**3.4.6.2      Atmosphere**

The agent must function in a pure oxygen environment at 3.5 to 5.0 psia or in a 75% nitrogen/25% oxygen environment throughout the pressure range of 5.0 to 14.7 psia.

**3.4.6.3      Thermal**

The agent must maintain its stability and effectiveness throughout a temperature range of 35°F to 110°F and also throughout a relative humidity range of 30 to 90% at 75°F, dry bulb.

**3.4.6.4      Gravitational**

The agent must be functional in a gravity field of zero to one-g.

**3.4.6.5      Safety**

The agent must meet spacecraft safety requirements defined as nonflammable, non-corrosive, nontoxic and nonvolatile.

3.4.7      System Requirements

3.4.7.1      Stability

The agent must have a long shelf life (2 years) and be compatible with the storage container.

3.4.7.2      Residue

The agent must have a minimum residue and not promote clogging.

3.4.7.3      Compatibility

The agent must be functionally compatible with maintenance procedures of existing life support and habitability systems.

3.4.8      Crew Requirements

The agent must be aesthetically acceptable to male and female flight type personnel. The agent must maintain flight type personnel in a flight type situation at an aesthetically acceptable condition when used in accordance with a technique that is similar to terrestrial personal hygiene practices.

## SECTION 4.0

### SANITATION AGENT/TECHNIQUE SELECTION (TASK II)

Early in the program FI/FRD realized that it would be impossible to select one product that would meet the different requirements of personal hygiene and systems maintenance. To facilitate the final selection procedure, the active ingredients were divided into two categories, surfactants and biocides. The basic selection process for both components was similar, and Figure 4-1, "Sanitation Agent Selection Procedure" is a diagram of the selection procedure.

The selection procedure consisted of the following steps:

- Inventory
- Preliminary Selection
- Selection Evaluation
- Trade-Off Data Matrix
- Use Applicability Study
- Final Selection
- Use Techniques
- Evaluation Testing

#### 4.1 INVENTORY

The first step in agent selection was the preparation of an inventory of surface active agents and biocides. This was prepared from a literature survey and contacts with the manufacturers. The inventory was used to perform the preliminary selection phase.

##### 4.1.1 Surface Active Agents

The surfactant inventory consisted of compounds that fell into the following classes:

- I. Anion - active agents (anionics)
  - A. Soaps
    - 1. Alkali soaps
    - 2. Metallic soaps
    - 3. Amine soaps
    - 4. Rosin soaps

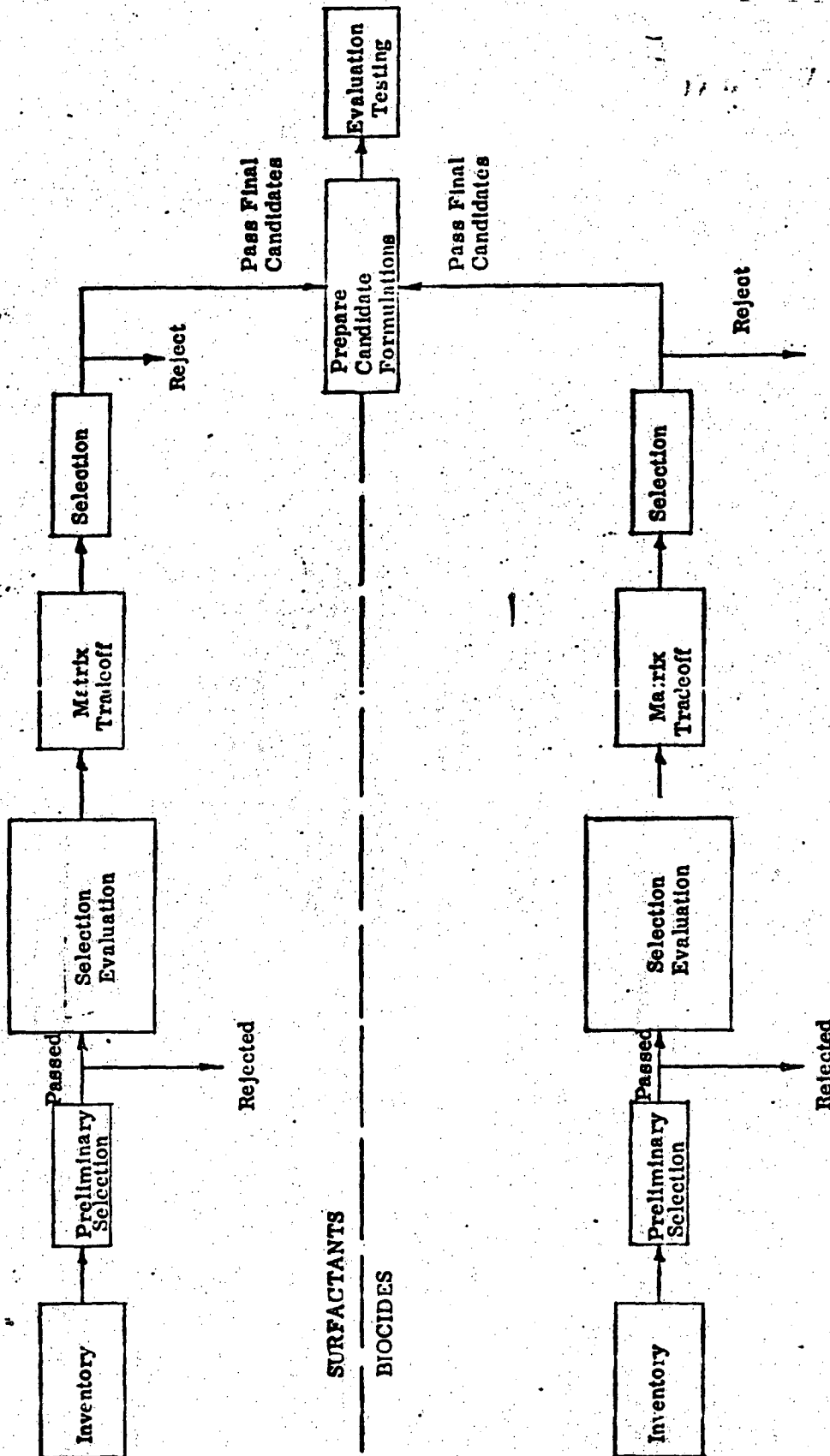


Figure 4-1. Sanitation Agent Selection Procedure



- B. Sulfuric acid esters (sulfated compounds)
  - 1. Sulfated alcohols
  - 2. Sulfated oils
  - 3. Miscellaneous compounds
- C. Sulfonic acid derivatives (sulfonated compounds)
  - 1. Alkane sulfonates
  - 2. Alkyl aromatic sulfonates
- II. Cation - active agents (cationics)
  - A. Simple amine salts
  - B. Quaternary ammonium compounds
  - C. Amino amides and imidazolines
- III. Nonionics
  - A. Ether linkage
  - B. Ester linkages
  - C. Ether - Esters
  - D. Amide linkages
- IV. Ampholytic surfactants
  - A. Amino and carboxy groups
  - B. Amine and sulfuric ester or sulfonic groups

#### 4.1.2 Biocidal Agents

The biocides are agents that are capable of attenuating organisms that could cause contamination by bacterial colonization and thereby render a system aesthetically, functionally or medically unacceptable.

There were numerous physical and chemical agents that could satisfy the definition of a biocide. Initially both of these types of biocides were considered in the compilation of the inventory.

In order to facilitate the preliminary selection procedures, the biocide inventory was prepared on a class level in two separate listings: chemical biocides and physical biocides.

**4.1.2.1 Chemical Biocides**

- a) Phenolics
- b) Alcohols and aldehydes
- c) Soaps
- d) Dyes
- e) Quaternary ammonias
- f) Heavy metals
- g) Halogens
- h) Gaseous compounds
- i) Oxidizing agents
- j) Antibiotics and enzymes

**4.1.2.2 Physical Biocides**

- a) Heat
- b) Radiation
- c) Ultrasonics
- d) Filtration
- e) Pressure
- f) Drying
- g) Centrifugation
- h) Electrohydraulics
- i) Laser beams

**4.2 PRELIMINARY SELECTION**

Preliminary surface active and biocidal agent selection was performed using the previous established Phase I requirements on toxicity, microbial effectiveness, safety and detergency. All those surfactants and biocides whose properties could not fulfill these requirements were rejected.

**4.2.1 Surface Active Agents**

Based upon preliminary screening, literature studies concerning use application, and an analysis of space sanitation agent requirements, Class II - cationic

surfactants and Class IV amphoteric surfactants were eliminated from further evaluation because:

- a) Cationic surface active agents are primarily used for their germicidal properties and show little value as detergent or wetting agents. These compounds offer a greater disadvantage of chemical incompatibility when combined with anionic surfactants.
- b) Amphoteric surface active agents consist primarily of compounds containing either carboxy or phosphoric ester as their acidic group and a nonquaternary nitrogen as their basic group. These compounds are used primarily for their bactericidal effects. In solution, they may chemically act by a cationic or anionic reaction, which would limit their combination with many germicides and other surfactants.

#### 4.2.2 Biocidal Agents

Preliminary selection of the biocidal agent was made on a class basis rather than on an individual basis. The biocides were treated in this manner since their properties are attributable to the class to which they belong. Preliminary biocidal agent selection was based primarily on the following criteria.

- a) Toxicity
- b) Microbial effectiveness
- c) Compatibility with the spacecraft environment

All those biocidal agents that met the above criteria passed this phase of the procedure and were evaluated further. All those biocidal agents that did not were rejected and no further evaluations were necessary.

Initially all those chemical agents that were selective in their effectiveness (i.e., narrow spectrum) against microorganism were immediately rejected. These included such classes of compounds as dyes, soaps and enzymes and antibiotics.

The physical methods of reducing biocidal activity were rejected in toto since they would appear to be incompatible with both human tissue and some of the materials used on the spacecraft. In addition, considerable and costly development of these methods would be necessary.

After the preliminary screening, the following compounds were selected for further evaluation:

- a) Quaternary ammonia compounds
- b) Chlorine and iodine compounds

#### 4.2.2.1 Quaternary Ammonia Compounds

The quaternary ammonium compounds are selectively more active against gram positive organisms than against the gram negative types, although the differences sometimes may not be very great. Pseudomonas aeruginosa is the most resistant among the gram negative organisms to the effects of quaternary ammoniums compounds. Although the quaternaries are ineffective as lethal agents against acid-fast organisms, several attenuate the growth of the acid-fast organisms, thereby exerting effective control.

Quaternary ammonium compounds are not considered to be effectively sporicidal or fungicidal even though manufacturers sometimes claim that they are. Testing using an inactivator shows that the test organisms can be recovered from culture.

The great advantage to using a quaternary ammonium compound is that in concentrations used for various purposes they are relatively nontoxic. For instance, 400 mg of cetylpyridinium chloride per kg body weight has proved lethal to rabbits, but 100 mg administered daily for periods up to 4 weeks produced no significant pathological changes (Warren, M.R., Becker, T.J., Marsh, D.G. and Shelton, R.S. 1942. Br. J. Pharmacol. 74).

In common with most other disinfectants, the antibacterial activities of the quaternaries are markedly suppressed in the presence of organic matter of any sort. This is probably due to the direct action of the quaternary with the added protein.

Absorption plays an important part in the process of disinfection by quaternaries, exhibiting both good and bad features. Being surface active, they are readily absorbed on any material. All surfaces, therefore, are left with a residual layer of the compound which continues to exert its antibacterial effect. This is also disadvantageous because, in testing solutions, one has always to be alert to the carry over effect when solutions are handled in pipettes, test tubes and similar containers.

As well as being affected by organic matter of biological origin, the quaternary ammonium compounds are incompatible with certain other groups of compounds. In particular, they are completely inactivated by anionic compounds including soaps, and by compounds such as sodium lauryl sulfate as well as several nonionic compounds, e.g., Lubrol and Tween 80.

Acidity also decreases the microbial effectiveness of many quaternaries to such an extent that at pH 3 their germicidal activities almost disappear. Temperature also affects their activity. Broadly speaking, it would appear that only about half the concentration is necessary to produce the same killing effect at 37°C as at 20°C.

The bactericidal action of the quaternaries has been attributed to the inactivation of enzymes, denaturation of essential cell proteins and disruption of the cell membrane. There is an insufficient amount of quaternary ammonia in most lethal solutions to cause a general protein denaturation but some selective action in this direction is feasible and it is most likely that the most sensitive protein in the cell, enzyme protein, is the first to succumb. This could explain the differential activities of the quaternaries between gram positive and gram negative bacteria.

The phenomenon of bacteriostasis exhibited by the quaternaries almost certainly involves reversible reactions of one type or another, reversible inactivation of enzymes or other reversible interferences with other cell mechanisms. If this effect is maintained for a long period of time, the capacity of the organism to recover is lost, even when they are placed in a more favorable environment.

Quaternaries are practically nontoxic and nonirritating. At the concentrations normally used there, they can be applied to the more delicate membrane areas. They are used in the food industries where they are used to disinfect food utensils, drinking glasses and dairy equipment. However, they are not as effective against the *Pseudomonas* group. Increased concentrations are necessary to effectively control this group of organisms.

#### 4.2.2.2 Chlorine and Iodine Compounds

Chlorine compounds are highly effective as bactericidal, sporicidal and fungicidal agents. The germicidal effect of the chlorine compounds, although these compounds are germicidal by virtue of their available chlorine content, is dependent upon chlorine

release. The rate at which chlorine is released is dependent upon a number of external factors, temperature, pH, concentration and light. Most chlorine compounds are light and temperature sensitive and must be stored in a cool and dark place. Increased alkalinity will result in the loss of almost all the available chlorine, thus causing the solution to lose its disinfectant properties. The bactericidal efficiency of chlorine is reduced in the presence of organic matter. The outstanding exception to this is the chloramines which are used in the treatment of sewage. Chloramine can be used as a topical disinfectant and in the disinfection of food utensils. Their germicidal effect is due the release of NaOCl and not the production of free chlorine.

Iodine is a highly reactive element and it is this reactivity which makes it an effective germicide. Iodine is an extremely effective bactericidal agent with all types of bacteria being killed at the same level of concentration. Iodine's effectiveness is reduced in the presence of organic matter. Iodine is almost equally effective against both spore and vegetative bacteria, provided the cells are in solution. If they are not in solution or on a damp surface, killing time is increased. Iodine is an effective fungicidal and fungistatic agent. Iodine is considered to be nontoxic. However, it can be shown that iodine can be harsh and an irritant on some skins and can cause severe blistering if carelessly handled. Iodine solutions stain badly and leave a brown sticky residue that must be removed by rinsing.

The intense chemical reactivity of chlorine is undoubtedly the reason for its outstanding characteristic as a rapid and effective germicide even at high dilutions. The lethal action is probably due to the direct action of the chlorine on some vital constituent of the cell e.g., protoplasm or enzyme system. This effect is probably due to the hydrolysis of the chlorine compound to give hypochlorous acid, and secondly the bactericidal activity can be probably associated with the concentration of undissociated molecules of hypochlorous acid.

The reactivity of iodine is similar to that of chlorine but the mode of action differs markedly. The disinfecting action of iodine is probably due to the result of the production of free iodine molecules which combine with protein substances of the cell. The formation of the acid, hypoiodous, probably does not take any part in the disinfection process which probably is a direct halogenation procedure.

The iodine and chlorine compounds appear to be the most effective biocidal compounds. The basic differences are in their mode of action, residue formation and reactivity in the presence of organic matter. The bactericidal effectiveness of both chlorine and iodine is reduced in the presence of organic matter, e.g., fecal matter, urine and vomitus. However, the chloramines are less susceptible to the adverse influences of organic matter and generally retain their effectiveness under these conditions.

#### 4.3 SELECTION EVALUATION

The surfactants and biocides that passed preliminary selection were then evaluated using the selection evaluation sheets. Figure 4-2 is the "Surface Active Agent Selection Evaluation Sheet." Figure 4-3 is the "Biocide Selection Evaluation Sheet."

Different numerical values were assigned to each factor depending upon the relative importance of the action to satisfying the Task I requirements. The factor values chosen for each biocide and surfactant evaluated were then multiplied by the weighted multiplier and the total divided by the number of effects studied. This value, the final selection factor, was listed on the bottom of the selection evaluation sheets.

##### 4.3.1 Surface Active Agents

The categories used to evaluate surface active agents were as follows:

- a) Solubility in Water -- The primary solvent for a sanitizing agent is usually water. Task I requirements were best satisfied by the application of water soluble surfactants. Any other solvents, e.g., benzene, toluene, and alcohol, could be irritating to the skin tissue and incompatible with the environmental systems.
- b) Surface Tension -- The reduction of surface tension in an aqueous solution was necessary for efficient hard surface wetting. As a general rule, good wetting agents, detergents, and emulsifiers will reduce the surface tension of aqueous solutions appreciably.
- c) pH, Reaction of Solution -- In order to meet the pH requirements, the surface active agent had to fall within the pH range of mildly acidic to neutral, 5.5 - 7.0. This pH range will maintain the acid mantle condition of the skin.

Agent No.	SURFACE ACTIVE AGENTS				FAIRCHILD REPUBLIC DIVISION															
Agent:	Trade Name Generic Class				Factor (F)	Multiplier (M)	M x F	No. of Effects												
Effect Studied	SELECTION EVALUATION																			
Solubility in water	<table border="1"> <tr> <td>Insoluble</td> <td>Miscible</td> <td>Dispersible</td> <td>Soluble</td> </tr> <tr> <td>0</td> <td>1</td> <td>2</td> <td>3</td> </tr> <tr> <td></td> <td></td> <td></td> <td>4</td> </tr> </table>				Insoluble	Miscible	Dispersible	Soluble	0	1	2	3				4	2			
Insoluble	Miscible	Dispersible	Soluble																	
0	1	2	3																	
			4																	
Surface Tension	<table border="1"> <tr> <td>Poorer Lowering</td> <td>Better Lowering</td> </tr> <tr> <td>0</td> <td>1</td> </tr> <tr> <td></td> <td>2</td> </tr> </table>				Poorer Lowering	Better Lowering	0	1		2	2									
Poorer Lowering	Better Lowering																			
0	1																			
	2																			
pH, Reaction of solution	<table border="1"> <tr> <td>Alkaline</td> <td>Strongly Acid</td> <td>Near Neutral</td> <td>Mildly Acidic</td> </tr> <tr> <td>0</td> <td>1</td> <td>2</td> <td>3</td> </tr> <tr> <td></td> <td></td> <td></td> <td>4</td> </tr> </table>				Alkaline	Strongly Acid	Near Neutral	Mildly Acidic	0	1	2	3				4	2			
Alkaline	Strongly Acid	Near Neutral	Mildly Acidic																	
0	1	2	3																	
			4																	
Toxicity External	<table border="1"> <tr> <td>High Irritation</td> <td>Mild Irritation</td> <td>Slight Irritation</td> <td>No Irritation</td> </tr> <tr> <td>0</td> <td>1</td> <td>2</td> <td>3</td> </tr> <tr> <td></td> <td></td> <td></td> <td>4</td> </tr> </table>				High Irritation	Mild Irritation	Slight Irritation	No Irritation	0	1	2	3				4	2			
High Irritation	Mild Irritation	Slight Irritation	No Irritation																	
0	1	2	3																	
			4																	
Compatibility to acids and alkalis	<table border="1"> <tr> <td>Not stable</td> <td>Stable</td> </tr> <tr> <td>0</td> <td>1</td> </tr> <tr> <td></td> <td>2</td> </tr> </table>				Not stable	Stable	0	1		2	2									
Not stable	Stable																			
0	1																			
	2																			
Compatibility to other surfactants	<table border="1"> <tr> <td>Not Compatible</td> <td>Slightly Compatible</td> <td>Moderately Compatible</td> <td>Completely Compatible</td> </tr> <tr> <td>0</td> <td>1</td> <td>2</td> <td>3</td> </tr> <tr> <td></td> <td></td> <td></td> <td>4</td> </tr> </table>				Not Compatible	Slightly Compatible	Moderately Compatible	Completely Compatible	0	1	2	3				4	1			
Not Compatible	Slightly Compatible	Moderately Compatible	Completely Compatible																	
0	1	2	3																	
			4																	
Wetting Action	<table border="1"> <tr> <td>Poor</td> <td>Good</td> <td>Excellent</td> </tr> <tr> <td>0</td> <td>1</td> <td>2</td> </tr> <tr> <td></td> <td></td> <td>3</td> </tr> </table>				Poor	Good	Excellent	0	1	2			3	3						
Poor	Good	Excellent																		
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		3																		
Emulsifying Properties	<table border="1"> <tr> <td>Poor</td> <td>Good</td> <td>Excellent</td> </tr> <tr> <td>0</td> <td>1</td> <td>2</td> </tr> <tr> <td></td> <td></td> <td>3</td> </tr> </table>				Poor	Good	Excellent	0	1	2			3	3						
Poor	Good	Excellent																		
0	1	2																		
		3																		
Foam Height Initial	<table border="1"> <tr> <td>250 mm</td> <td>100 mm</td> <td>50 mm</td> <td>10 mm</td> </tr> <tr> <td>0</td> <td>1</td> <td>2</td> <td>3</td> </tr> <tr> <td></td> <td></td> <td></td> <td>4</td> </tr> </table>				250 mm	100 mm	50 mm	10 mm	0	1	2	3				4	3			
250 mm	100 mm	50 mm	10 mm																	
0	1	2	3																	
			4																	
Foaming Height after 3 minutes	<table border="1"> <tr> <td>225 mm</td> <td>75 mm</td> <td>25 mm</td> <td>0 mm</td> </tr> <tr> <td></td> <td>1</td> <td>2</td> <td>3</td> </tr> <tr> <td></td> <td></td> <td></td> <td>4</td> </tr> </table>				225 mm	75 mm	25 mm	0 mm		1	2	3				4	3			
225 mm	75 mm	25 mm	0 mm																	
	1	2	3																	
			4																	
Detergency	<table border="1"> <tr> <td>Poor</td> <td>Good</td> <td>Excellent</td> </tr> <tr> <td>0</td> <td>1</td> <td>2</td> </tr> <tr> <td></td> <td></td> <td>3</td> </tr> </table>				Poor	Good	Excellent	0	1	2			3	3						
Poor	Good	Excellent																		
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		3																		
Comments: Final Selection Factor = $\frac{\Sigma (M \times F)}{\text{No. of Effects Studied}}$ = <table border="1" style="display: inline-table; width: 100px; height: 20px;"></table>																				

Figure 4-2. Surface Active Agent Selection Evaluation Sheet



Agent No.	BIOCIDAL AGENTS				FAIRCHILD REPUBLIC DIVISION				Factor (F)	Multiplier (M)	M x F	No. of Effects				
Agents:	Trade Name	Generic	Class													
Effects Studied													SELECTION EVALUATION			
MICROBIAL EFFECTIVENESS	Bactericidal	Not Effective	Poorly Effective	Moderately Effective	Very Effective	0	1	2	3	4	2					
	Sporicidal	Not Effective	Poorly Effective	Moderately Effective	Very Effective	0	1	2	3	4	2					
	Fungicidal	Not Effective	Poorly Effective	Moderately Effective	Very Effective	0	1	2	3	4	3					
	Virucidal	Not Effective	Poorly Effective	Moderately Effective	Very Effective	0	1	2	3	4	1					
AGENT EFFECTIVENESS	Effective Concentration	10 Percent	5 Percent	1 Percent	1 ppm	0	1	2	3	4	2					
	Desired effect on set time	Needs Activation	One Hour	15 Minutes	Immediate	0	1	2	3	4	1					
	Tenacity	Evaporates Instantly	One Hour	Six Hours	Twenty-four Hours	0	1	2	3	4	2					
	Stability	3 Months	6 Months	One Year	Three Years	0	1	2	3	4	1					
HUMAN COMPATIBILITY	Toxicity to Man	Extreme Irritant	Mild Irritant	Slight Irritant	Non Irritant	X	Lethal	Mild Irritant	Slight Irritant	Non Irritant	3					
	Aesthetic	Offensive	Mildly Offensive	Slightly Offensive	Non Offensive	0	1	2	3	4	1					
SAFETY	Safety Risk	Hazardous	Moderately Hazardous	Slightly Hazardous	Non Hazardous	0	1	2	3	4	3					
	Comments Final Selection Factor = $\frac{\sum (M \times F)}{\text{No. of Effects Studied}} = \frac{\boxed{\phantom{000}}}{\boxed{\phantom{000}}} = \boxed{\phantom{000}}$															

Figure 4-3. Biocide Selection Evaluation Sheet

- d) **Toxicity, External --** The surface active agent should not show any signs of irritation to the human skin or exposed outer tissue (eyes, oral mucosa, etc.).
- e) **Compatibility to Acids and Alkalies --** The surface active agent had to be compatible with other chemical materials which were used in the final formulation. Any added materials for the final formulation were either acidic or alkaline in nature.
- f) **Compatibility to Other Surfactants --** It is advantageous that the surfactants evaluated be compatible with one another, due to the possibility of a final formulation containing more than one class of surfactant in combination.
- g) **Wetting Action --** An important property of a surface active agent is the ability to improve the rate and degree of the wetting of various surfaces by water, particularly oily or greasy surfaces which are otherwise difficult to wet. A common procedure for measuring wetting efficiency is the Draves Test. It establishes the concentration of wetting agent necessary to cause the sinking of a weighed cotton skein in a given time in an aqueous solution of a surfactant. It is a function of time versus concentration.
- h) **Emulsifying Properties --** To meet the requirements of the solubilizing of the oil components of metabolic wastes, the surfactant had to possess good emulsifying activity. An emulsion is a dispersion of one liquid in another. Two types of water emulsions were possible, oil-in-water (O/W) and water-in-oil (W/O). The emulsification property was determined by two functions; (1) to decrease the interfacial tension between the liquids, enabling easier formation of the greatly extended interfaces, and (2) to stabilize the dispersed phase against coalescence once it is formed.
- i) **Foam Heights --** In order to maintain controlled use of the agent in the space environment and to meet the established requirements, maximum

and minimum foam heights were evaluated. A preferable range of a stable foam fell between 10 to 50 mm initially and 0 to 25 mm after three minutes.

- j) Detergency -- The cleaning efficiency of a surfactant solution is due to its ability to solubilize fatty soils. The ability of a surfactant solution to remove oily soil from a surface is closely related to the contact angle between the solution, oil spot and surface. The contact angle is also dependent on the wetting ability of a compound, therefore, a surfactant which showed good wetting ability usually possessed good detergent action.

The materials selected for further evaluation ranked above these final selection factors for each surfactant class.

<u>Surfactant Class</u>	<u>Final Selection Factor</u>
Nonionic	> 6.4
Anionic	> 5.9
Amphoteric	> 5.9

The following surface active agents passed the selection evaluation phase and were accepted for subsequent study:

- |    |  |                  |
|----|--|------------------|
| 1. | Cetaphil Lotion                        | Class - Anionic  |
|    | Sodium lauryl sulfate plus base        |                  |
| 2. | Emcol 4110 M                           | Class - Anionic  |
|    | Half ester sulfosuccinate              |                  |
| 3. | Duponol QC                             | Class - Anionic  |
|    | Sodium lauryl sulfate                  |                  |
| 4. | Emcol 4300                             | Class - Anionic  |
|    | Disodium sulfosuccinate                |                  |
| 5. | Nonisol 250                            | Class - Nonionic |
|    | Fatty acid ester of higher polyglycols |                  |
| 6. | Triton CF-21                           | Class - Nonionic |
|    | Not applicable                         |                  |

- |    |   |                         |
|----|---|-------------------------|
| 7. | <b>Alrosol</b>                                    | <b>Class - Nonionic</b> |
|    | <b>Alkanolamide of diethanolamine</b>             |                         |
| 8. | <b>Tween 60</b>                                   | <b>Class - Nonionic</b> |
|    | <b>Polyoxyethylene (20) sorbitan monostearate</b> |                         |

### 4.3.2 Biocidal Agents

The categories used to evaluate biocidal agents were as follows:

- a) **Microbial Effectiveness --** Microbial effectiveness measures the ability of each biocide to reduce the total number of microorganisms. This ability is classified in terms of the agents, bactericidal, sporicidal, fungicidal and viricidal effectiveness.
- b) **Effective Concentration --** This is a measurement of the minimum concentration of biocide needed to effectively kill microorganisms and at the same time be compatible with human tissue and spacecraft materials. The lower the concentration, the higher the rating.
- c) **Desired Effect Onset Time --** This is a measurement of the amount of time necessary to obtain a sanitary condition. The more rapid the effect, the more desirable the biocide.
- d) **Tenacity --** This is a measurement of the ability of a biocide to retain its effectiveness and contact with the material on which it is acting. It is effected by surface properties and formulation of the sanitation agent.
- e) **Stability --** This is a measurement of the biocide's ability to retain its effectiveness when time and environmental conditions are varied.
- f) **Human Toxicity --** This is a measurement of the biocide's compatibility with both internal and external human tissue. Since these biocides are inherently toxic due to their antimicrobial properties, a certain amount of human toxicity is expected. However, this amount by necessity must be low since dermatitis, vomiting or systemic poisoning could occur. To insure that the selected sanitation agent was completely compatible with both internal and external human tissue, the values selected for these categories were multiplied together.

- g) Aesthetic -- This is a measurement of the relative effects of the odors produced by the biocide during use.
- h) Safety -- This was a measurement principally of the biocides corrosiveness, flammability and volatility, but other criteria were considered (e.g., physiological reactions).

The primary objective of this selection phase was to evaluate those biocidal agents that had passed the preliminary selection procedure. The weights assigned to each of the study parameters were calculated to give a mean value of 6.0. All those biocidal agents that fell below this level were rejected. All those that were evaluated higher than this level were accepted and evaluated on the Trade-Off Data Matrix sheets.

A more critical evaluation of the results of this selection phase led to the conclusion that it was possible to have a candidate whose mean value fell below 6.0, and because of a unique property, be acceptable and even recommended. Conversely, it would be possible to reject a candidate whose mean value exceeded 6.0 for reasons of an adverse critical nature. For example, if a biocidal agent was rated as 6.5 but was extremely toxic to humans, the biocide would be rejected.

The following biocidal agents were accepted for further study at the end of this selection procedure:

a) Quaternary Ammonia Compounds

- Cetol
- Diabactol
- Roccal

b) Halogens

- G. S. I.
- Biopal VRO-20
- Mikroklene
- Wescodyne
  - Ketjensept TC
  - Betadyne

#### 4.4 TRADE-OFF DATA MATRIX

After the initial analysis and rating of the candidate surface active agents and biocidal agents, those candidates rated at or above the selection criteria score were subsequently evaluated on separate trade-off data matrix sheets. This analysis eliminated those surface active agents and biocidal agents that did not meet the safety, toxicity or effectiveness requirements.

##### 4.4.1 Surface Active Agents

The trade-off data matrix for the final selected surface active agents is presented in Table 4-1 "Surfactants Trade-Off Data Matrix." The surface active agents were compared to one another using the criteria established in the selection evaluation phase.

##### 4.4.2 Biocidal Agents

The trade-off analysis for the biocides was performed in two parts, the trade-off data matrix and use applicability data.

The trade-off data matrix for the biocides is presented in Table 4-2 "Biocides-Trade-Off Data Matrix." The primary consideration in this evaluation was the biocides ability to effectively perform the requirement. The agents were rated on their ability to meet these criteria on an acceptable or not acceptable basis. The following are the effective limits for each category.

<u>Effect</u>	<u>Acceptable</u>	<u>Rating</u> <u>Not Acceptable</u>
Bactericidal	slightly effective	not effective
Sporicidal	slightly effective	not effective
Virucidal	slightly effective	not effective
Fungicidal	slightly effective	not effective
Effective concentration	less than or equal to 1%	greater than 1%
Desired effect onset time	less than or equal to 5 minutes	greater than 5 minutes
Toxicity to man (external and internal)	nontoxic	slightly toxic
Aesthetic	non-offensive	slightly offensive

TABLE 4-1. SURFACTANTS - TRADE-OFF DATA MATRIX

Effects Studied	1	2	3	4	5	6	7	8												
Solubility in Water *	D	D	S	S	S	S	S	S												
Surface Tension	27	37	27	30	41	35	35	38												
pH, Reaction of Solution	6.2	6.2	8.0	6.0	6.0	6.5	7.0	6.8												
Toxicity External *	NT	NT	NT	NT	NT	NT	NT	NT												
Compatibility to Acids and Alkalies *	C	C	C	C	C	C	C	C												
Compatibility to other Surfactants *	G	G	G	G	E	E	E	E												
Wetting Action *	E	E	E	E	G	G	G	G												
Emulsifying Properties *	E	E	E	E	E	E	E	E												
Foam Height, Initial	10	40	175	140	35	10	60	15												
Foaming Height after 3 Minutes	5	35	150	125	15	5	35	10												
Detergency *	E	E	E	E	G	E	G	G												
Selection Evaluation Value	7.0	6.2	6.0	6.0	7.0	6.7	6.5	7.0												
*KEY S - Soluble																				
D - Dispersible																				
T - Toxic																				
NT - Non-toxic																				
C - Compatible																				
NC - Not compatible																				
E - Excellent																				
G - Good																				

\*KEY

TABLE 4-2. BIOCIDES - TRADE-OFF DATA MATRIX

Effects Studied	1	2	4	12	13	14	15	16	17										
Agent/Technique																			
Bactericidal	X	X	X	X	X	X	X	X	X										
Sporicidal	X	X	X	X	X	X	X	X	X										
Fungicidal	X	X	X	X	X	X	X	X	X										
Virucidal	X	X	X	X	X	X	X	X	X										
Effective Concentration	X	X	X	X	X	X	X	X	X										
Desired Effect on Set Time	X	X	X	X	X	X	X	X	X										
Toxicity to Man	X	X	X	X	X	X	X	X	X										
External	X	X	X	X	X	X	X	X	X										
Internal	X	X	X	X	X	X	X	X	X										
Aesthetic	X	X	X	X	X	X	X	X	X										
Tenacity	X	X	X	X	X	X	X	X	X										
Stability	X	X	X	X	X	X	X	X	X										
Safety Risk	X	X	X	X	X	X	X	X	X										
Agent #1 = Cetol																			
#2 = Dibactol																			
#4 = Roccal																			
#12 = G.S.I.																			
#13 = Bipal (R) VRO-26																			
#14 = Mikrokane																			
#15 = Wescodyne (R) T.C.																			
#16 = Ketjensept (R) T.C.																			
#17 = Betadyne																			

X = Acceptable, - = Not Acceptable



Tenacity	greater than or equal to one hour	less than one hour
Stability	greater than or equal to three months	less than three months
Safety	nonhazardous	slightly hazardous

The use applicability data is presented in Table 4-3. This was a simple trade-off analysis to match the applicable biocidal agents with the functional requirements for waste control, personal hygiene, shower and equipment cleansing. The purpose here was to rate the biocides in their ability to best satisfy the requirement. This was rated on an applicable or nonapplicable basis for each of the selected biocides.

#### 4.5 BIOCIDE AND SURFACE ACTIVE AGENT SELECTION

The final phase of the sanitation agent selection procedure consisted of two separate selections. The first step was the selection of the candidate biocide or biocides and the second step was the selection of the candidate surface active agents.

##### 4.5.1 Biocidal Agent

The final biocide selection was based entirely upon the candidate biocides ability to satisfy the following requirements:

- Toxicity
- Safety (includes corrosion, flammability and volatility)
- Microbial Effectiveness

Based upon these evaluations, the following agents were selected as having the best chance of meeting most of the Task I requirements:

- Cetol
- Roccal
- Betadyne
- Chloramine T

In analyzing the trade-off data matrix sheets and use applicability sheets, the quaternary ammonia compound Cetol appears to be capable of satisfying the Task I personal hygiene, shower, laundry and dishwashing requirements (Ref. Table 4-3). In addition, Cetol is capable of satisfying the requirement of maintaining sanitary conditions in the potable water supply (Ref. Table 4-3).

TABLE 4-3. USE APPLICABILITY DATA

Agent / Sanitation Function	Waste Control	Personal Hygiene	Dishwashing	Laundry	Shower	Water Supply	ECS
Cetol	-	X	X	X	X	X	X
Dibactol	-	X	X	X	-	-	-
Roccal	-	X	X	X	-	-	X
GSI	-	X	X	-	X	-	-
Biopal VRO-20	-	X	X	-	X	-	-
Mikroklene	-	X	X	-	X	-	-
Wescodyne	-	X	X	-	X	-	-
Ketjensept TC	X	-	X	X	X	-	X
Betadyne	-	X	-	-	X	-	-

X Indicates Applicable Agent for Cleansing and/or Bacterial Inhibition  
- Indicates Non Applicable

If the components of the potable water system are sterilized, then Cetol, the least toxic of the compounds (according to testing conducted by the Food and Drug Administration (FDA) ) must be used. If the water must be sterilized, then a Chloramine T or Iodine tablet would be used.

Although Cetol is not effective against all types of microorganisms, its lack of oral toxicity and low residue (very little or no rinsing needed) were such that any difficulties caused by its lack of a strong bactericidal effect could not preclude its selection as the spacecraft sanitation agent for personal hygiene. Any deficiencies caused by its lack of a strong bactericidal effect were eliminated by decreasing the time between usage.

Chloramine T was selected as the spacecraft sanitation agent for equipment maintenance. This biocide does not leave a residue and does not possess a strong chlorine odor since its microbial effectiveness depends upon the release of sodium hypochlorite and not free chlorine. Chloramines are less susceptible to the presence of large amounts of organic material and maintain their effectiveness to a greater extent than any other compound. In fact, chloramines are used in sewage and waste treatment plants because of the above mentioned ability.

As stated above, the biocides of choice are Chloramine T and Cetol. Since Betadyne and Roccal are widely accepted as primary sanitation agents, it is important that the reasons for their nonselection be elucidated.

Roccal is an effective germicide capable of being formulated as a liquid or aerosol. It has the same basic properties as Cetol. However, it is more toxic than Cetol, greater concentrations are needed to maintain the same microbial effectiveness levels as Cetol and for this reason it was rejected.

Betadyne has been selected for use on Skylab and is used extensively as the surgical scrub of choice in most hospitals. Betadyne is effective against a broad spectrum of microorganisms. It is used both as a topical pre- and post-operative antiseptic and as a surgical scrub. However, there are no environmental criteria to meet, the amount of rinse water available is unlimited and there is no need to disinfect large amounts of waste material. Betadyne has been rejected as the spacecraft sanitation agent for the following reasons:

- a) Effectiveness depends upon the release of free  $I_2$ , which is incompatible with the spacecraft environment

- b) Has undesirable staining properties
- c) Iodine compounds in effective concentration leave a residue which is sticky and must be rinsed
- d) Iodine compounds produce a pungent odor in hot water
- e) Iodine compounds are unstable when diluted to concentrations that are not sticky or staining
- f) Iodine compounds are rendered ineffective in the presence of large amounts of organic material
- g) Fumes produced by iodine compounds could be toxic to mucous membranes

#### 4.5.2 Surface Active Agent Selection

The final surface active agent selection was based upon the selected candidate agent's ability to satisfy the following requirements:

- Compatibility (must be compatible with selected biocidal agents)
- Toxicity
- Detergency

Based upon surfactant applications, preliminary selection, and selection evaluation the cosmetic grade of sodium lauryl sulfate, which is the major component of Cetaphil lotion, a mild cleaning agent, can best meet Phase I requirements. This surfactant is used in industrial and household cleaners, soap products, and cosmetic formulations. Sodium lauryl sulfate is chemically nontoxic and is extremely mild with human skin and exposed outer tissue. Its emulsifying property allows complete effectiveness when placed in contact with oils and other organic matter. The detergency of this compound is excellent, showing particular effectiveness on hard surface greasy soil. Sodium lauryl sulfate produces a higher foam than most anionic surfactants, however. The foam that is produced is tightly celled and stable, making it more desirable if any sudsing action is necessary. If little or no sudsing action is desired, additional ingredients in the formulation can virtually eliminate most foaming properties of this compound. The exceptional wetting and spreading characteristics of this surfactant will help attract and entrain small particles of grit and dust.

The primary disadvantage of this compound is its anionic chemical nature, which makes it incompatible with cationic surfactants and germicides. Therefore, another

surface active agent was needed to allow the formulation of a spacecraft sanitation agent containing Cetol. The surface active agent selected was Nonisol 250. Nonisol 250 is a nonionic surface active agent that looks like a whitish wax. Its surface active agent properties are acceptable as evidence by its selection evaluation rating which is the same as the Cetaphil lotion (sodium lauryl sulfate).

## SECTION 5.0 SPACECRAFT SANITATION AGENT FORMULATION

The previous sections have described the procedures that were followed in evaluating candidate biocidal and surface active agents. In formulating the selected biocidal and surface active agents, careful consideration was given to concentration, solubility, stability, incompatibility and space vehicle material restrictions. Therefore, each spacecraft sanitation agent is expressed in an optimized formulation within the scope of this program.

### 5.1 PURPOSE

The development of a list of ingredients which would satisfy the Task I requirements and produce a more stable, potent and effective product was the main objective in the formulation of the sanitizing agent.

The kind of problem that may be encountered in formulating can often be related to the physical and chemical properties of the materials involved, e.g., the chemical incompatibility of anionic surfactants and germicides.

The ideal situation would be the complete physical and chemical compatibility of all components of the sanitizing agent.

The formulation consists of the following major components:

- Active ingredients -- The components which bring about the desired activity of the agent, e.g., the germicide and surface active agents.
- Solvents -- The dispersing medium of the agent, which effects no permanent change on the active ingredients. Each component is usually soluble in the solvent system, e.g., water, propylene glycol.

Depending upon the dosage form desired (aerosol or lotion base), the following additional components will be employed as they are needed:

- Preservatives -- Chemical substances used to prevent decomposition or fermentation of the formulation, e.g., methyl paraben, benzoic acid.
- Thickeners -- A chemical substance which increases the viscosity of the preparation to the desired viscosity index, e.g., carboxy methylcellulose.

- Foam stabilizer -- A surface active agent which is used to maintain a desired foam height or determine the type of foam which is desired, e.g., alkanolamide.
- Antifoaming agents -- A surface active agent which prevents the formation of a high foam, by the formation of a stable emulsion, e.g., cetyl, stearyl alcohol.
- Antioxidants -- A chemical substance which inhibits the oxidation of certain components of the formulation, e.g., sodium bisulfite.
- Emulsifiers -- A surface active agent which is used to form a stable oil-in-water or water-in-oil emulsion, e.g., Tween 20.
- Perfume and certified colors -- Chemical substances which may be added to the formulation to impart aesthetic qualities.

## 5.2 SELECTED FORMULATIONS

Based upon the criteria established in the Task I and Task II reports, formulations were developed for spacecraft sanitation agents for both the personal hygiene and system maintenance areas. Several formulations were tested and rejected because of inferior consistency or separation of materials.

The consistency of the systems maintenance agent was purposely made "heavy" or viscous to entrain soil, whereas the personal hygiene agent was purposely prepared "light" or less viscous to facilitate easy spreading.

### 5.2.1 Systems Maintenance Sanitation Agent Formulation

The selected formulation for the system maintenance sanitation agent is as follows:

Phase A --	Cetyl alcohol	1.7%
	Stearyl alcohol	2.25%
Phase B --	Chloramine T	0.3%
	Duponol WAQ	
	(sodium lauryl sulfate)	5.0%
	Propylene Glycol	7.0%
	Distilled water	q. s. 100 cc

This formulation was originally prepared in 120 cc batches, but has also been prepared in larger batches.

5.2.2 Personal Hygiene Sanitation Agent Formulation

The selected formulation for the personal hygiene sanitation agent is as follows:

Phase A --	Glycerol monostearate	6.0%
	P. E. G. distearate	4.0%
	Tween 60	5.0%
	Cetyl alcohol	1.5%
	Isopropyl palmitate	4.5%
	Cetol	0.5%
Phase B --	Nonisol 250 (Ciba-Geigy)	5.0%
	Propylene glycol	5.0%
	Distilled water	q.s. 100 cc

This formulation was prepared in 100 ml batches, but has also been prepared in larger batches.



## SECTION 6.0

### EVALUATION TESTING (TASK III)

The purpose of evaluation testing was to test the effectiveness of both of the selected sanitation agents. Quantitative test data was collected on the performance of both of the sanitation agents in a normal terrestrial environment. Selected spacecraft environmental parameters were used to evaluate both of the selected sanitation agents performances in simulated spacecraft environments. The sanitation agents were evaluated during this test program for both performance and environmental criteria.

#### 6.1 PERFORMANCE CRITERIA

The following performance criteria were evaluated:

- Microbial effectiveness
- Sanitation and cleansing effectiveness
- Sudsing and rinsing characteristics
- Residue

##### 6.1.1 Microbial Effectiveness

The microbial effectiveness of both of the selected sanitation agents was determined by the results obtained from the Kolmer test and the use-dilution bactericidal test.

##### 6.1.1.1 Kolmer Test

The Kolmer test determines the highest dilution of a disinfectant capable of restraining the growth of the test organism for a stated period of time. It is an extremely sensitive test and yields sharply defined results. Standard Federal and Drug Administration (FDA) materials and techniques are used. The results are expressed in terms of the highest bacteriostatic and bactericidal dilutions. The following test results were obtained from the manufacturers of the selected sanitation agents.

- a) Cetol (Fine Organics Co.) -- The manufacturer of Cetol suggests that Cetol concentrations of 1:128,000 were lethal for the typhoid, dysentery and cholera bacteria; whereas it was necessary to employ considerably greater concentrations to destroy the remaining gram-negative organisms when tested by this method.

- b) Chloramine T (R. W. Greef & Co.) -- The manufacturer of Chloramine T suggests that, for routine disinfection purposes, 0.3% by weight (3 gms to 1 liter) is sufficient. However, under special circumstances such as the presence of large numbers of potentially infectious organisms, a dosage of 0.5% by weight is recommended (5 gms to 1 liter).

#### 6.1.1.2 Use-Dilution Bactericidal Test

The use-dilution bactericidal test determined the bactericidal activity of the selected organisms. This test evaluates the effectiveness of the dilution at which the disinfectant is to be employed in practice including the correct diluent. The selected sanitation agents were tested against test organisms obtained from the American Type Culture Collection. The tests with Chloramine T were repeated using organic matter since this agent would be primarily used in areas containing large amounts of organic material. The Cetol tests were placed in a 37°C (to simulate body temperature) incubator since this sanitation agent would be used to maintain acceptable levels of personal hygiene.

Based upon the results of the use-dilution bactericidal tests, the following statement can be made:

- Microbial effectiveness of Chloramine T is not appreciably affected by the presence of fecal matter.
- Chloramine T should remain in contact with the contaminated area for at least five minutes.
- Cetol should be applied to the skin for at least a five-minute time period.

#### 6.1.2 Sanitation and Cleansing Effectiveness

The sanitation and cleansing effectiveness of the Chloramine T formulation was tested using vomitus, feces and urine. In addition, the formulation was used to clean plates, pots and table tops in the cafeteria. The sanitation and cleansing effectiveness of the Cetol formulation was tested on the hands of a selected subject.

##### 6.1.2.1 Sanitation Effectiveness

The waste material (feces, urine and vomitus) was spread over a sterile surface and allowed to dry. A quantitative culture of the dried waste material was prepared. The formulation containing Chloramine T was spread over the surface and allowed to remain

in contact with the debris for 5 minutes, after which time, the surface was wiped clean with a dry wipe. Quantitative microbial samples of the clean surface were taken. Water was not used as a rinse at any time during this test. The ambient humidity during repeated tests ranged between 40 and 80 percent. Although this deviates from the contract specification, the humidity changes are not significant in effecting the performance of the agent.

A similar test using the personal hygiene agent was also performed. The subject's hands were microbially sampled before the agent was applied and immediately following application of the agent. Water was not used as a rinse at any time during this test.

Prior to the application of the Chloramine T formulation, the feces contained  $10^{10}$  microorganisms/gm. After five minutes contact time, no organisms were recovered. The vomitus sample contained  $10^6$  microorganisms/gram prior to Chloramine T application. After five minutes contact time, no organisms were recovered. The urine was negative both before and after application of the sanitation agent.

Prior to the application of the Cetol formulation, microbial cultures showed the presence of  $10^3$  microorganisms. After the Cetol formulation was removed, the total number of organisms was reduced by 90%. If a greater reduction of the microbial flora is desired, a water rinse should be used following the Cetol formulation application.

#### 6.1.2.2 Cleansing Effectiveness

The cleansing effectiveness of the agent was determined by the general appearance of the area cleaned. Chloramine T was used to clean plates, pots and table tops in the cafeteria. Dried fecal material, vomitus and urine were also removed with Chloramine T. A dirty desk top was selected and the agent was applied and then removed with a dry wipe. Water was not used during this test. Humidity varied as in subsection 6.1.2.1.

Greasy cooking pans in the company cafeteria were "washed" with the agent using only dry wipes. The agent was applied freely, allowed to stand for 15 seconds, and wiped clean.

Cetol was applied thoroughly to the hands of the selected subject. A dry wipe was used to remove the residue. The general appearance of the skin area was observed both before and after the application of the agent.

The vomitus and dried fecal material were entirely removed from the petri dish without the observation of any particulate material. There was no particulate material or large dirt spots observed on the hands of the test subject. The kitchen pots were grease-free and suitable for cooking.

#### 6.1.3 Residue Testing

Residue is a function of the nature of the agent, the surface to which it is applied and the soil it engages. If the agent can be absorbed tenaciously or form a complex with the surface, the residue buildup is either a self-limiting event or can be an accumulative process. To evaluate the residual effect of both sanitation agent formulations, the selected agents were applied to typical usage areas. Chloramine T was applied to a desk top and Cetol to a test subject. The same test subject evaluated visually and sensually the amount of residue present. The test subject found that there was no residue present either visually or sensually on the tested surface areas.

#### 6.1.4 Sudsing and Rinsing Characteristics

This testing was not necessary since, in their present formulations, the agents produce minimum sudsing characteristics. During manufacture of the agents, the foam height of Chloramine T was measured at less than 4 mm. The Cetol foam height was calculated to be 4 mm. However, since they are in a cream base, they do not produce any suds.

Rinsing has not been measured since the recommended agent usage on all materials does not include a water rinse. In the laundry area, it was not necessary to measure the rinsing effect since a compound similar to Chloramine T is commercially used.

### 6.2 ENVIRONMENTAL CRITERIA

The selected sanitation agents were evaluated in terms of the following environmental criteria:

- Flammability
- Storage stability
- Chemical compatibility of materials

#### 6.2.1 Flammability

The purpose of this test was to ascertain the flammability of the sanitation agents, in compliance with criteria established in the Fairchild proposal to the contract.

As the agents are aqueous and incapable of combustion while intact, flammability testing was limited to evaporation and flash point measurements, as might occur if a container were ruptured during an accident and the contents spilled on a hot surface.

Analysis of the flammability conditions pertinent to the sanitation agents following use indicate that there will only be a molecular layer of absorbing reactive points on the applied surfaces. These surfaces will afford a high degree of heat sinking, thereby limiting the need for flammability testing in accord with MSC-D-NA-0002, "Procedures and Requirements for the Flammability and Outgassing Evaluation of Manned Spacecraft Nonmetallic Materials." Flammability testing was conducted according to the procedures associated with the tag closed tester and Cleveland open cup.

The spacecraft sanitation agents as constituted did not spark or ignite at low temperatures (below 93°C, 200°F). Extremely high temperature ranges are necessary before these agents will ignite. It is reasonable to conclude that, in the normal conditions of the spacecraft environment, these agents will not pose any safety problems due to their flammability.

#### 6.2.2 Storage Stability

The purpose of these tests were to ascertain the stability of the product over a range of environmental conditions. The criteria for acceptance were:

- a) Stability of the emulsion, i.e., no "cracking" or phase separation
- b) No discoloration or visible signs of oxidation

Emulsions are generally temperature sensitive, becoming more viscous in cold and more fluid in hot conditions. Because the dispensing of the product is intended to be in positive displacement containers (i.e., tubes, squeeze bottles, or pressure cans) viscosity changes are not critical and, therefore, not quantified under stability.

The thirty day stability test is adequate for product evaluation, but industry practice frequently is to observe shelf life over a period of years.

#### 6.2.2.1 Thermal Stability

Closed bottles containing approximately 100 cc of the agents were placed in thermally controlled environments for 30 days at the following temperatures.

- a) -10°C (14°F) -- This was the temperature of an existing freezer in the laboratory. This test is beyond the requirements of the contract specifications.
- b) 4°C (39°F) -- This deviated from the test plan temperature because the specified test temperature is at the phase change temperature of water. 4°C is common refrigerator temperature, and this was selected for convenience. The temperature difference is not significant in terms of the properties of an emulsion.
- c) Room temperature, 22°-27°C (71°-80°F) -- This was the temperature range of the laboratory during testing.
- d) 40°C (104°F) -- This is the temperature of an existing incubator in the laboratory, and close to the contract specification of 110°F.

The emulsions remained intact at all temperatures above freezing.

#### 6.2.2.2 Atmospheric Stability

Open bottles containing approximately 100 cc of the agents were placed in gaseous environments for thirty days at room ambient temperature.

- a) 78% nitrogen/21% oxygen -- This deviates from the contract specification of 75% nitrogen/25% oxygen and is normal earth atmosphere. The 4% difference is not significant in terms of the properties of the products.
  - 1) One bottle of each agent was maintained at room ambient pressure of approximately 14.7 psi
  - 2) One bottle of each agent was placed in a bell jar at a pressure of 5 psi
- b) 100% oxygen -- An open bottle of each agent and a piece of aluminum on which each agent had been applied and dry-wiped off were placed in the 5 psi 100% oxygen environment.

There was no discoloration in any of the samples, which would have been presumptive evidence of oxidation. Because the bottle caps were off, there was evaporation which resulted in a thickening of the emulsion at the air/liquid interface. The metal plates showed no visible signs of oxidation.

### 6.2.3 Chemical Compatibility of Materials

The purpose of this test was to determine the effects of the spacecraft sanitation agent formulations on possible spacecraft construction materials. An aliquot of spacecraft sanitation agent formulations was placed on the following test swatches:

- Aluminum 6061 - O
- Stainless steel - Class 1
- Vespell
- Polyimide
- Teflon

The test swatches were placed in a dessicator. Uninoculated samples of all the test swatches were also placed in the dessicator as a control. A water solution of the sanitation agent at the correct concentration was placed in the dessicator. This was done to ascertain if the sanitation agent produced vapors that were incompatible with these materials. The dessicator was placed in a 40°C (104°F) incubator for 30 days.

There was no evidence of corrosion, either microscopically or macroscopically, on the stainless steel or aluminum test samples. There was no visible evidence of any chemical reaction on the teflon or vespell samples. However, microscopically there appeared to be a general smoothing out of the rough surface observed on the uninoculated samples. The polyimide sample microscopically also showed evidence of the smoothing out of the rough surface observed on the uninoculated sample. There also was a stain, easily observable by the naked eye, where the Chloramine T and Cetol had been placed. There was no evidence of any effects caused by the vaporization of the Chloramine T and Cetol in the petri dish.

Chloramine T and Cetol can be used extensively on all types of materials without a water rinse with the exception of polyimides, where the only effect is staining. If the system maintenance agent is used on a surface containing a polyimide, a water rinse should be incorporated into the cleaning operation. This would probably prevent the appearance of any stains.

The smoothing out of the rough edges of the vespell and teflon samples is probably a results of the seepage of the oils, contained in the sanitation agent, into the lattice work of the samples. This resulted in a polishing out of the rough edges.

## SECTION 7.0 SANITATION AGENT - USE TECHNIQUES

### 7.1 INTRODUCTION

These techniques were designed to maintain sanitary conditions in the waste management system, food system, shower and laundry, personal hygiene area, potable water system and ECS expendables during the treatment, handling and storage of waste products inherent to these areas. This included wastes on exposed surfaces that must be transferred from use areas to specific locations on the normal waste management facilities. The final sanitation agent usage selection for each of these areas was dependent upon testing. The following sections discuss sanitation agent use-techniques for the major subsystems.

### 7.2 WASTE MANAGEMENT SYSTEM

The waste management subsystem should be cleaned and sanitized by incorporating the Chloramine T in the flush water. Any spills should be treated as outlined below in Section 7.2.1 "Metabolic Wastes" and Section 7.2.2 "Biomedical Monitoring."

The fecal storage compartments in the majority of the advanced collection system concepts are ventilated by collection and odor control air flow during the fecal collection function. Therefore, any noxious and/or toxic vapors generated by the Chloramine T would have been analyzed and noted. However, in the concentration considered this was a problem which was not encountered.

#### 7.2.1 Metabolic Wastes

Metabolic wastes (e.g., feces, urine and vomitus), barring any metabolic monitoring requirement are cleaned and sanitized using the spacecraft sanitation agent for equipment maintenance in the following sequence:

<u>Function</u>	<u>Equipment</u>
Clean debris	Wet wipe or vacuum cleaner
Area cleansing	Equipment maintenance agent
Disperse equipment maintenance agent	Wet wipe
Remove excess fluid and debris	Dry wipe



The soiled wipes are placed in a waste collection bag. The waste collection bag is transferred to a waste storage bag and subsequently treated according to the procedures outlined in Section 7.8.

#### 7.2.2 Metabolic Monitoring (Optional Procedure)

The cleansing technique and sanitizing technique used in the treatment of metabolic wastes must be changed if the urine, feces, and vomitus must be included in the metabolic monitoring program. Initially, the material must be removed and placed inside the biomedical collection unit prior to surface cleansing. The rest of the cleaning and sanitizing sequence would then follow the procedures outlined in Section 7.2.1.

### 7.3 FOOD SYSTEM

The food system wastes are cleaned and sanitized as follows:

The food cans are collected in a general purpose bag, compacted, placed in a waste storage and subsequently treated according to the procedures outlined in Section 7.8. Food trays and utensils are sanitized using the spacecraft sanitation agent for equipment maintenance according to the procedures outlined below in Section 7.3.1 and Section 7.3.2.

#### 7.3.1 Liquid Wastes

Liquid wastes (e.g., food spillage) are cleaned and sanitized in the following sequence:

<u>Function</u>	<u>Equipment</u>
Spill collection	Dry wipe
Area cleansing	Equipment maintenance agent
Disperse sanitizing agent	Wet wipe
Remove excess fluid and debris	Dry wipe

The soiled wipes are then placed in a waste collection bag, transferred to a waste storage bag, and subsequently treated according to the procedures outlined in Section 7.8.

### 7.3.2 Solid Wastes

Solid wastes (e.g., food) are cleaned and sanitized in the following sequence:

<u>Function</u>	<u>Equipment</u>
Spill collection	Wet wipe and/or vacuum cleaner
Area cleansing	Equipment maintenance agent
Disperse sanitizing agent	Wet wipe
Remove excess fluid and debris	Dry wipe

The soiled wipes are then placed in the waste collection bag, transferred to a waste storage bag and subsequently treated according to the procedures outlined in Section 7.8.

## 7.4 PERSONAL HYGIENE

This sanitation agent does not need a water rinse after it has been applied to the hands and face. However, a wet wipe or a facial rinse is desirable. The schedule of whole body washes should be not less than three times a week. A wet wipe or a water rinse is recommended after a whole body wash when used in a regular program of personal hygiene.

## 7.5 SHOWER AND LAUNDRY

### 7.5.1 Shower

The shower is cleaned and sanitized between usage events using the systems maintenance agent (or the personal hygiene agent) and a wet wipe, or the agent could be incorporated into the water spray system. The concentration level of the sanitation agent needed would be low. The shower system should not be used for at least 30 minutes following the disinfection procedure to insure maximum disinfection.

### 7.5.2 Laundry

If a biocide is incorporated into the final rinse, there is no need to sanitize the washing machine. If not, the systems maintenance agent should be used followed by a wet wipe, on an as-needed basis.

## 7.6 POTABLE WATER SYSTEM

The attachments and fittings of the potable water system should be treated with the personal hygiene agent followed by a wet wipe.

## 7.7 MISCELLANEOUS TRASH, ECS EXPENDABLES, ETC.

The NASA Housekeeping Study Contract with Republic, NAS9-10662, defined the wastes that will be generated on extended life orbital stations with crews of from 6 to 100 men.

This study concluded that the only trash that requires sanitation is that which is already contaminated with bacteria or that which can support microbial growth. Typical items that fall into these categories are expendables from the ECS system and residues from biological and biochemical experiments, and medical wastes.

Environmental surfaces can be contaminated with liquid or solid wastes. The cleaning treatment depends upon the particular wastes and quantities involved and was the same as outlined above for the food system in Section 7.2.1 and Section 7.2.2.

## 7.8 WASTE TREATMENT AND HANDLING

According to data obtained in Contract NAS9-11995 all contaminated waste products (e.g., metabolic, laboratory, medical, etc.) are placed into waste collection bags and immediately transferred to a waste storage bag. The waste storage bag is then closed and a disinfectant capsule containing a fumigant, e.g., formaldehyde, is broken.

All other waste products are collected in the waste collection bag. These collection bags do not have to be immediately placed inside the waste storage bag, but can be held until they are filled or routinely removed. After these wastes have been placed in the waste storage bag, they are compacted. The waste storage bag is then closed and the disinfectant capsule is broken.

Food cans are stored in waste storage bags and compacted on a daily basis. The compacted material is placed in a waste collection bag. After the calculated capacity of the waste collection bag is reached, the bag is closed and the disinfectant capsule is broken.

## 7.9 USE - TECHNIQUES SPACECRAFT FUNCTIONAL AREAS

Table 7-1, "Use - Techniques Spacecraft Sanitation Agent for Personal Hygiene" and Table 7-2, "Use - Techniques Spacecraft Sanitation Agent for Equipment Maintenance" describe the handling and treatment of the waste products found in each functional area. The table provides minimal, acceptable and optimal handling techniques.

**TABLE 7-1. USE - TECHNIQUES SPACECRAFT SANITATION  
AGENT FOR PERSONAL HYGIENE**

Function	Use - Techniques		
	Minimal	Acceptable	Optimal
Oral Hygiene	Use as toothpaste, remove with dry wipe.	Use as toothpaste, remove with wet wipe.	Use as toothpaste, followed by water rinse.
Face and Hand Wash	Apply directly on hands and face, followed by dry wipe.	Apply directly on hands and face, followed by dry wipe and then a wet wipe.	Apply directly on hands and face, followed by water rinse.
Whole Body Wash	Apply to all parts of the body, followed by dry wipe.	Apply to all parts of the body, followed by dry wipe, then wet wipe.	Apply to all parts of the body, followed by shower.
Hair Hygiene	Apply to scalp and hair cutting instrument after hair is cut, followed by wet wipe.	Apply to scalp and hair cutting instrument after hair is cut, followed by water rinse.	Apply to scalp, followed by shower.
Shaving Capability	Clean shaver followed by dry wipe.	Clean shaver, followed by dry wipe.	Clean shave, followed by wet wipe.

**TABLE 7-2. USE - TECHNIQUES SPACECRAFT SANITATION  
AGENT FOR EQUIPMENT MAINTENANCE**

Function	Use - Techniques		
	Minimal	Acceptable	Optimal
Food System Clean Dishes and Utensils	Apply agent, re- move with dry wipe.	Apply agent, re- move with dry wipe, then use wet wipe.	Use a dishwasher with a specific detergent.
Clean Table Tops	Apply agent, re- move with dry wipe.	Apply agent, re- move with dry wipe, then use wet wipe.	Apply agent, re- move with water rinse.
Remove Spills and Debris	Wipe up spill. Apply agent, re- move with dry wipe.	Wipe up spill. Apply agent, re- move with dry wipe, then use wet wipe.	Apply agent in aerosol formula- tion, remove with water rinse.
Laundry	Wash in hand sink with the agent and rinse.	Incorporate a spe- cific agent into wash- ing machine cycle.	Incorporate a spe- cific agent into wash- ing machine cycle.
Shower	Apply agent and follow by water rinse.	Apply agent and follow by water rinse.	Incorporate agent into shower system.
Potable Water System <sup>(1)</sup>	Wipe contamin- ated units with agent. Remove with dry wipe.	Use agent in an aerosol for application.	Use agent in an aerosol for application..
Laboratory Con- taminated Material	Apply agent, place in waste collection bag.	Place in waste collection bag. Use aerosol.	Autoclave and dispose.
Laboratory Equip- ment (Reusable)	Apply agent, then wipe with dry wipe.	Place in container. Use aerosol follow- ed by water rinse.	Autoclave and reuse.
Waste Management System Collector Seat	Apply agent, then wipe with dry wipe.	Apply agent, wipe with dry wipe, then wet wipe.	Apply agent in aerosol formulation followed by wet wipe.
Waste Material	Collect in collec- tion bag, add dis- infectant tablet	Collect in collection bag and vacuum dry	Collect in commode. Use disinfectant, flush

Note (1) Personal hygiene sanitation agent is recommended for this function.

SECTION 8.0  
CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

The following are the findings of the spacecraft sanitation agent contract:

1. Two sanitation agents must be used in order to satisfy the requirements set forth in the Statement of Work and defined in the requirements study. Their formulas are:

a. Sanitation Agent for Personal Hygiene

Phase A --	Glycerol monostearate	6.0%
	P. E. G. distearate	4.0%
	Tween 60	5.0%
	Cetyl alcohol	1.5%
	Isopropyl palmitate	4.5%
	Cetol	0.5%
Phase B --	Nonisol 250 (Ciba-Geigy)	5.0%
	Propylene glycol	5.0%
	Distilled water q. s.	100 cc

b. Sanitation Agent for Equipment Maintenance

Phase A --	Cetyl alcohol	1.7%
	Stearyl alcohol	2.25%
Phase B --	Chloramine T	0.3%
	DuPont WAQ (sodium lauryl sulfate)	5.0%
	Propylene glycol	7.0%
	Distilled water q. s.	100 cc

2. The selected spacecraft sanitation agents may be used with or without a water rinse.
3. The selected spacecraft sanitation agents are completely compatible with the spacecraft environment and materials. However, a water rinse is recommended whenever possible and especially when the spacecraft sanitation agents are used on surfaces containing polyimide or vespell.

4. The selected spacecraft sanitation agents may have commercial application in water restricted situations, e.g., camping, boating, traveling, military operations, etc.

## 8.2 RECOMMENDATIONS

Because of certain problems relating to formulation, stability and use, it is recommended that serious consideration be given to pressure-packed or aerosol\* formulations. The space program should benefit from twenty years of knowledge gained by the drug and cosmetic industry, specifically that aerosol preparations have many advantages over conventional formulations. One need only look at the proliferation of aerosol products in cleaners and polishes for almost everything, cosmetics and toilet goods, drugs, special foods, paints and lubricants, and many others.

The principal advantages of an aerosol product are:

1. Convenience -- No spill, no mess. Only the exact quantity used is dispensed. The container is a convenient size and shape.
2. Formulation flexibility -- Because the active ingredients can be separated until the moment they are dispersed, incompatibility problems are minimal. Stability problems are also minimized because the product is never exposed to air or light.
3. Product property flexibility -- Based upon the requirements of the product's use, a numerous range of product properties is possible by combinations of valve, propellant and formulation. Viscosity can be produced by foaming, instead of by the addition of nonactive ingredients or unsuitable emulsions.
4. Special space application -- Conventional bladder cans will provide positive product dispensing even in zero-gravity. The cans can be fitted with valves that interface with habitability systems. Because individual cans can be taken from stores as needed, the need for large reservoirs is eliminated. The cans can be conveniently and aesthetically integrated into housekeeping and personal hygiene modules. All aerosol hardware is

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\* In the trade, the term aerosol is no longer applied solely to fine liquid in air dispersions, but used generally to describe any pressure can product.

"off-the-shelf", resulting in a considerable savings in development costs.

Aerosol preparations are beyond the scope of this contract, as they were not proposed by FRD in response to the RFP, they are not cited in the contract, and there are no funds allocated for aerosol packaging.

Typical formulations for aerosol sanitizing agents are:

Aerosol Formulations

1. Waterless Hand Cleaner

Germicide	1.0%
Surface active agent	5.0%
Propylene glycol	15.0%
P. E. G. 400 monostearate	3.0%
Methyl, propyl parabens	1.0%
Sodium bisulfite	1.0%
Perfume	
Certified colors	
Purified water q. s.	100 cc

Above mixture 80% plus propellant 20%

2. Aerosol Skin Cleanser

Germicide	1.0%
Surface active agent	4.0%
Nonionic surfactant	4.0%
Oleyl alcohol	2.0%
Triethanolamine sulfate	3.0%
Purified water	86.0%

Above mixture 90% plus propellant #55/10%

3. Aerosol Shaving Cream Base

Germicide	1.0%
Surface active agent	5.0%
Oleyl alcohol	1.0%
Nonionic surfactant	3.0%
Triethanolamine sulfate	5.0%
Sodium lauroyl sarcosinate	2.0%
Metyl, propyl parabens	1.0%
Purified water	72.0%
Propellant	10.0%



NASA should continue the space sanitation effort with a Development Program for Pressure Packaging of Sanitizing Agents for Housekeeping and Personal Hygiene consisting of the following elements:

1. Identification of potential applications
2. Trade-off against alternate methods
3. Select candidate products
4. Define constraints
  - Safety
  - Toxicity
  - Materials
  - Aesthetics
  - Operability
  - Human factors
5. Define product requirements
6. Develop formulations
  - Propellant
  - Valves
  - Container
  - Product concentrate
7. Testing
  - Stability testing
  - Product performance in 1 "g" and 0 "g"
8. Documentation

In addition to its application to sanitation, pressure packing has the following potential for space use:

**Sanitation and Personal Hygiene**

- Hand and body soaps for regular use
- Special soaps for disinfecting and heavy cleaning
- Deodorants
- Hair control (including depilatories)
- Dentifrices and oral rinses

**Medical**

- Antiseptic and anesthetic
- Spray-on bandage
- Nasal decongestants
- Inhalation therapy (anti-nauseant, cough control)
- Anti-pruritics
- Noninvasive injectables
- Preservatives

**Maintenance**

- Anti-static spray
- Fungicidal agents
- Sanitation agents for galley, WMS, etc.
- Lubricants
- Insulations